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Effects of Mining-Derived Metals Contamination on Native Floristic Quality

By Esther D. Stroh, Matthew A. Struckhoff, and Keith W. Grabner

Administrative Report

U.S. Department of the Interior
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Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
square meter (m^2)	0.0002471	acre
hectare (ha)	2.471	acre
square kilometer (km^2)	247.1	acre
square meter (m^2)	10.76	square foot (ft^2)
square centimeter (cm^2)	0.1550	square inch (ft^2)
	Volume	
cubic meter (m^3)	35.31	cubic foot (ft^3)
	Concentration	
milligrams per kilogram (mg/kg)	1	parts per million (ppm)
milligrams per kilogram (mg/kg)	1	micrograms per gram (ug/g)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)
metric ton (mT)	1.1023	short ton (t)

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Summary

We assessed the floristic quality of vegetation growing in a variety of sites associated with lead mining activities and in relatively undisturbed reference sites in southeast Missouri. Floristic quality was assessed using two standard measures: Mean C and FQI. Sites associated with mining activities included untreated mine and mill waste, revegetated mine and mill waste, remediated mine and mill waste, and intact native soils adjacent to mine waste disposal sites and surrounding a lead smelter. Reference sites were located on native soil on high, flat, local maxima (“summits”) or low flats (“bottoms”) with minimal evidence of human disturbance. We quantified relations between floristic quality measures and concentrations of lead (Pb) and zinc (Zn) in the topsoil and subsoil, and the mean concentrations from both soil layers.

Multiple lines of analysis demonstrate a negative effect of metals, especially soil zinc concentrations, on plant communities. Two multivariate techniques, Nonmetric Multidimensional Scaling (NMS) and Regression Tree Analysis, identify Pb and Zn in the topsoil and subsoil as primary explanatory variables of community composition on native soils, and subsoil Zn as a primary explanatory variable on mine waste. Both techniques indicate

negative relationships between metals concentrations and floristic quality. Means tests show that plots on native soils with Pb concentrations above the Ecological Soil Screening Level (Eco-SSL) of 120 mg/kg (USEPA 2005b) have significantly lower floristic quality than plots with Pb concentrations below this level. Plots with subsoil and mean Zn concentrations above Ecological Soil Screening Level of 160 mg/kg (USEPA 2007a) have significantly lower floristic quality measures than those below this level. Plots with topsoil Zn concentration above 160 mg/kg have significantly lower FQI than plots with Zn concentration below 160 mg/kg. These same plots have lower Mean C than plots with Zn concentrations below an expert-identified threshold of 70 mg/kg (Kaputska 2007). Finally, univariate regression demonstrates significant negative relations between metals concentrations and floristic quality measures.

Using the regression equations, we calculated concentrations of Pb and Zn at which one could expect to see reductions of 10 and 20 percent in Mean C and FQI compared to the mean value of these measures on sites with concentrations below Eco-SSLs for lead and zinc. For Mean C, a ten percent reduction can be expected at concentrations of 713 mg/kg for Pb and 403 mg/kg for Zn. A twenty percent reduction can be expected at concentrations of 7,480 mg/kg for Pb and 2,515 mg/kg for Zn. For FQI, a ten percent reduction can be expected at concentrations of 1,010 mg/kg for Pb and 285 mg/kg for Zn. A twenty percent reduction can be expected at concentrations of 10,320 mg/kg for Pb and 1,264 mg/kg for Zn. Similar calculations can be made for either the topsoil or subsoil using the appropriate regression equations.

The negative effects of metals were more pronounced on native soil plots in relatively undisturbed conditions, indicating that elevated metals concentrations affect floristic quality where no other human disturbance is evident. However, even at highly disturbed sites on mine waste, higher Zn concentrations are associated with decreased floristic quality. This study demonstrates decreased floristic quality above Eco-SSLs for Pb and Zn, and nearly all mine waste plots exceeded these thresholds. This suggests that, even if mine waste were otherwise equivalent to native soils, elevated metals concentrations on mine waste would likely be associated with decreased floristic quality.

Introduction

Background

In response to a request from the Missouri Department of Natural Resources (MDNR), in collaboration with U.S. Fish and Wildlife Service (USFWS) as the Missouri Trustee Council, we assessed the floristic quality of vegetation growing in a variety of sites associated with lead (Pb) mining activities and in relatively undisturbed reference sites in southeast Missouri. Soils and vegetative communities adjacent to lead smelters, mine/mill waste and tailings disposal sites are known to contain elevated concentrations of metals including lead, cadmium (Cd) and zinc (Zn) (Kabata-Pendias and Pendias, 1992) and plants are known bioaccumulators of lead, zinc and other metals (Sudhakar and others, 1992; Taylor and others, 1992; Brown and others, 1995). Lead inhibits growth and enzymes required for photosynthesis, interferes with cell division and respiration, reduces water absorption and transpiration, and reduces chlorophyll and adenosine triphosphate (ATP) synthesis (Kabata-Pendias and Pendias, 1992). Although Zn is an essential micronutrient for plants, elevated soil Zn concentrations resulting from anthropogenic sources including mining and smelting activities can have toxic effects in plants (Chaney, 1993).

The effects of mining-derived metals contamination have been demonstrated on numerous agricultural plants in the field and in laboratory experiments (Andersson 1988, Das and others, 1997; Balsberg, 1998), but heavy-metal sensitivity of most native plants are unknown (Leyval and others, 1997; Fletcher and others, 1988). A search of the ECOTOX database using the 544 species found during this study yielded only 32 studies examining relationships between these plant species and Pb or Zn. Of these studies, only seven examined the phytotoxicity of either Zn or Pb on native species and only one examined community-level impacts (USEPA

2007b). In addition to the lack of phytotoxicity information for non-agricultural plant species, little research has been conducted to document effects of metals on the composition or quality of vegetative communities on mine waste, adjacent native soils, or soils surrounding smelters.

The United States Environmental Protection Agency (USEPA) Ecological Soil Screening Levels (Eco-SSLs) identify concentrations of contaminants in soil that are protective of ecological receptors that commonly come into contact with and/or consume soil biota (USEPA 2003a, 2005a, 2005b, 2007a). The Eco-SSLs are derived separately for plants, soil invertebrates, birds, and mammals. The values are presumed to provide adequate protection of terrestrial ecosystems. The Eco-SSL for terrestrial plants is 120 mg/kg for lead (USEPA 2005b). This value was derived primarily from studies of Pb effects on agricultural species, but did include data from a study of red maple (*Acer rubrum*), a native tree species commonly found in the study area (Davis and Barnes 1973). The maximum acceptable toxicant concentration for Pb derived from that study was 144 mg/kg (USEPA 2005b). Thus, the current Eco-SSL for Pb is more protective than the value suggested by Davis and Barnes (1973) for at least one locally common native tree species.

The Eco-SSL for terrestrial plants is 160 mg/kg for Zn (USEPA 2007a). This value was derived from studies of Zn effects on agricultural species, primarily oats (*Avena sativa*) and soybean (*Glycine max*). Much of the research on Zn phytotoxicity thresholds in plants has been carried out with agricultural species; there is little information about the effects of high Zn concentrations on nonagricultural plant species (Paschke and others 2006). Sixty-day Zn effective concentrations (EC50-shoot, EC50-root and EC50-plant) for non-agricultural plant species considered for reclamation use ranged from 56 to 371 mg/kg (Paschke and others 2006). As environmental concentrations of Zn approach higher ecological threshold values, it becomes more likely that more species will be harmed; at environmental concentrations substantially above the higher threshold values, serious and sustained injury to most or even all species can be expected (Kaputska 2007).

Cadmium is a naturally occurring rare element with no known essential or beneficial biological function (Eisler 1985 as cited in USEPA 2005a) and well-documented toxic effects to plants (reviewed in Das and others 1997), including native tree species (Kelly 1979, Dixon 1988). Increased Cd levels in soils can result from mining, processing and smelting of Zn and Zn-Pb ores and other industrial activities (Hutton 1983, USEPA 2005a). Cadmium is highly mobile and can have visible effects of chlorosis and stunting in plants at low concentrations (less than 1 mg/kg for some species; Das and others 1997). The low-level toxicity of Cd is reflected in the low Eco-SSL for Cd of 32 mg/kg; background soil concentration in the eastern U.S. is about 0.23 mg/kg (USEPA 2005a) and about the same in southeast Missouri agricultural soils (0.24 mg/kg, Holmgren and others 1993).

Native plant communities are composed of many species for which very few have known heavy metal toxicity concentrations. Species richness (number of species present) has been shown to decrease at increased soil Pb concentrations in historic mining districts (Clark and Clark 1981). Composition and structure of vegetation communities has been shown to be dependent on soil Pb and Zn concentrations (Thompson and Proctor 1983) and with time since Pb and Zn mine abandonment (Kimmerer1984). None of these studies specifically address the floristic quality of vegetation communities on mine wastes or heavy-metal contaminated native soils compared to surrounding native vegetation communities.

Floristic Quality Assessment

Species richness, or number of species present at a site, is the simplest measure of plant community diversity. More complex indices of biological integrity quantify conditions relative to those under little or no influence from human actions, and differ from simpler diversity measures (Angermeier and Karr 1994). Integrity indices measure a system's wholeness and exclude species not native to the system; a biota with high integrity reflects natural evolutionary and biogeographic processes (Angermeier and Karr 1994). In addition, measures based on species' relative abundance are more accurate than measures of species diversity or richness alone (Wilsey and others 2005). Biological integrity metrics are powerful tools for measuring community response to a variety of anthropogenic disturbances, including pollutants and toxic chemicals (Newman and Unger 2003).

A commonly utilized index of habitat integrity is the Floristic Quality Assessment (FQA) developed by Swink and Wilhelm (1979, 1994). This index is built upon the premises that native plant species differ in their sensitivity to disturbance and that a system's integrity can be measured by the suite and abundance of native species that occur there. Some species are generalists; they commonly occur across the landscape and are more tolerant of a wide variety of conditions or disturbances. Other species are found only in locations where there has been relatively little human influence and are indicators of less disturbed or modified habitat. In this particular study, the disturbance of interest is elevated soil concentrations of heavy metals due to the mining, processing and transport of extracted ore and mine waste.

There are two components to FQA: Mean C and the Floristic Quality Index (FQI). Each species in a geographic region is assigned a Coefficient of Conservatism, or "C" value from 0 to 10, based on its disturbance tolerance. Species with low C values (0-3) tend to be generalists that occur throughout the landscape in disturbed and undisturbed habitats. Species with high C values (8-10) require undisturbed systems where the natural processes to which that species has evolved are functioning. A species' C value reflects that species' ability to indicate that the ecological processes that shape and define a given habitat are functioning. Non-native species are not included in FQA because only the presence and proportion of conservative native species can define a natural area (Swink and Wilhelm 1994). Mean C is the arithmetic mean C value of all native species occurring in a sample unit. Mean C is independent of species richness (number of species present) and is therefore an appropriate measure for comparing the integrity of community types of inherently different richness. Swink & Wilhelm (1994) suggest that species inventories from sites of natural quality will attain a Mean C of 3.5 or higher. Those with high natural quality might be expected to have a Mean C of 4.5 or greater. The FQI is the product of Mean C and the square root of the native species richness. Sites with FQI values of 35 or higher are generally considered to be of natural quality, and sites with FQI values in excess of 45 are considered to be noteworthy natural remnants (Swink and Wilhelm 1994). Both Mean C and FQI are unitless.

Regional C values are assigned by expert panels familiar with species distributions and habitat and have been developed and tested in Missouri (Ladd 1993) as well as in Illinois (Taft and others 1997), North and South Dakota (Northern Great Plains Floristic Quality Assessment Panel 2001), Ontario (Oldham and others 1995), Ohio (Andreas and others 2004), Wisconsin (Wisconsin Floristic Quality Assessment 2002) and other locations. Although the assignation of C values is a somewhat subjective process, regionally-assigned C values have been shown to give identical conclusions of floristic quality compared to data-generated C values (Mushet and others 2002).

One specified use of FQA is comparison of floristic quality among different sites regardless of native community type; for example, forest, prairie and wetland (Swink and Wilhelm 1994). This technique has been used successfully to compare plant communities among different sites with different disturbance histories (Lopez and Fennessey 2002, Mushet and others 2002), and with different management practices (Higgins and others 2001). The index has been shown to increase with decreasing disturbance to surrounding land use (Lopez and Fennessy 2002) and with increasing time since restoration (Mushet and others 2002, McIndoe and others 2008). Typically, FQI values are typically higher at undisturbed natural sites than at restored sites (Mushet and others 2002, Rothrock and Homoya 2005). Very little research has focused on FQI in relation to soil metal concentrations. Kindscher (2007) found significantly higher FQI values in native prairie sites compared to naturally revegetated and to leveled, capped and revegetated chat piles in the Tri-State Mining District of southwest Missouri, but did not compare reference sites on native soil to contaminated native soil sites.

Environmental Setting

Southeast Missouri contains some of the highest concentrations of lead ore deposits in the world. Two major lead-producing areas of the Southeast Missouri Lead Mining District include the "Old Lead Belt" and the Viburnum Trend (Figure 1). Old Lead Belt mining began around 1720, and much of the land was denuded of timber by the early nineteenth century. Early mining in the Old Lead Belt consisted of individual, shallow workings scattered throughout the area. When large ore deposits were discovered in 1869 at a depth of about 100 meters (Norwine 1924), large-scale mining operations began and continued until 1972 (Missouri Department of Health 1996). Early mining separated ore from parent material using a physical separation procedure that yielded a coarse byproduct known as chat, which was typically deposited in large piles. Later, around 1930, mining companies adopted a chemical separation method that yielded a finer particulate waste—called tailings—which was deposited into valley-fill impoundments and other impoundments by way of a slurry pipeline (USFWS 2008, Missouri Department of Health 1996). Tailings generally contain higher concentrations of heavy metals than chat piles (USEPA 2007c). However, the chat in the Old Lead Belt has sufficiently high metals concentrations to warrant the more recent use of chemical separation to reprocess much of the previously produced chat (USWFS 2008). Today, large chat piles, tailings impoundments, and other mine/mill wastes characterize the landscape around major mining sites.

Mining in the Viburnum Trend is either relatively recent or ongoing, and has been dominated by large-scale operations. Nearly all mining in the area has been conducted in deep-shaft mines (300 meters or more), with a chemical separation process yielding tailings as a byproduct (The Doe Run Company 2009). Tailings are typically disposed of in valley-fill impoundments. Eroding mill tailings contaminate adjacent soil and Ozark streams and have led to contaminated aquatic food chains and loss of biota including mussels and crayfish (Schmitt and others 2007); ecological impacts to aquatic systems can result from seepage, surface runoff, and/or airborne dust from active mining areas (Besser and others 2009).

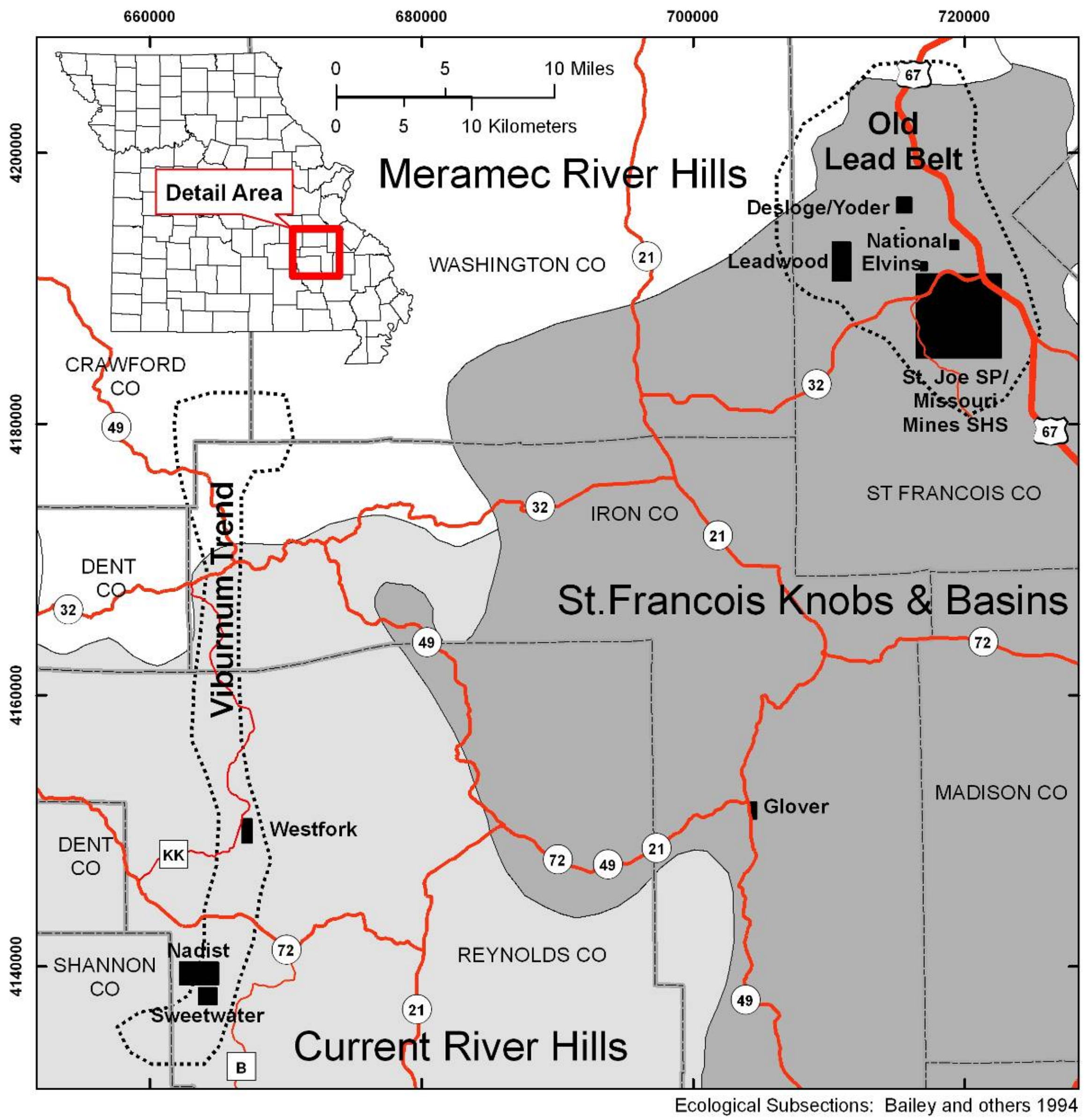


Figure 1. Location of southeast Missouri FQA sampling sites in relation to the Old Lead Belt and Viburnum Trend, and to Ecological Subsections.

Both mining districts are located in the Ozark Highlands Section of Missouri, an area that supports over 200 endemic species (Nigh and Schroeder 2002). The Ozarks are perhaps the oldest continuously exposed (neither submerged nor subsided) land mass in North America; the region has likely supported plant life for 100 million years, and was not glaciated during any of the last four major continental glaciation events. The continuous exposure and lack of glaciation has resulted in high levels of plant community diversity and species endemism (The Nature Conservancy Ozarks Ecoregional Assessment Team 2003). Presettlement vegetation was characterized by oak and pine woodlands and forests heavily influenced by aboriginal and natural fires (Guyette and Cutter 1991) and interspersed with small and large patches of other natural communities including fens, wetlands, and glades (The Nature Conservancy Ozarks Ecoregional Assessment Team 2003). The landscape is now dominated by second-growth forest; most of the Ozarks were logged between 1880 and 1920 (Cunningham and Hauser 1992).

The Old Lead Belt lies in the Meramec River Hills and St. Francois Knobs subsections of Missouri; the Viburnum Trend is located in both the Meramec River Hills and Current River Hills Subsections of Missouri (Nigh and Schroeder 2002; Figure 1). The Meramec River Hills Subsection is a hilly and rugged landscape dominated by steep slopes, narrow valley bottoms and cherty carbonate and sandstone-derived soils. Presettlement vegetation was mixed-oak and pine-oak woodland and forest (Nigh and Schroder 2002). The Current River Hills Subsection landscape ranges from hilly to deeply dissected with rocky soils derived from carbonate and sandstone substrates; presettlement vegetation was oak and pine forests and woodlands (Nigh and Schroeder 2002). The St. Francois Knobs Subsection is distinctive for its Precambrian age bedrock; the landscape varies from smooth igneous knobs to smooth dolomitic and sandstone basins to highly dissected areas similar to the other subsections. Presettlement vegetation was a mixture of forests, woodlands, glades and small prairies (Nigh and Schroder 2002).

Study Areas and *a Priori* Site Types

Study sites were located in three areas: the Old Lead Belt near Park Hills, Missouri; the Viburnum Trend in Reynolds and Iron Counties, Missouri; and near the inactive smelter at

Glover, Missouri. Sampling areas in the Old Lead Belt and Viburnum Trend were identified by the Missouri Trustee Council to represent the range of metals concentrations and condition of mine wastes and native soils. Mine waste sampling points included untreated mine waste (chat and tailings) as well as mine waste that had received some type of revegetation and/or remediation treatment such as seeding and/or fertilization. Native soil sampling points included a range of metals concentrations representing background (reference) soil levels for the region as well as sites with a range of metals concentrations, and plots receiving aerial deposition of heavy metals from the smelter.

We identified seven *a priori* site types to capture the desired range of conditions. Reference sites have soil surface Pb concentrations of less than 100 mg/kg and are located on two different landforms. "Reference summits" occur on high, flat, local maxima, have no mine waste and minimal evidence of human disturbance. "Reference bottoms" are low flats adjacent to intermittent streams, creeks and rivers, have no mine waste and minimal evidence of human disturbance. Summit and bottom landform types were selected in order to reflect the range of vegetation diversity in the region. Vegetation communities in riparian zones (bottoms) are among the most diverse community types in the Ozarks, while summits are among the least floristically diverse landforms in the Ozarks (Nigh and others 2000, Grabner 2001). "Contaminated native soil" plots are adjacent to mine waste, but without obvious deposition of mine waste or other human disturbance, and have surface soil Pb concentrations greater than 100 mg/kg. In terms of their proximity to mine waste and resulting elevated metals concentrations, these sites are synonymous with the term "transition zone soils" used in other research (USEPA 2006a). "Smelter-contaminated" sites occur on native soils downwind from the smelter at Glover, Missouri where there is a high probability of contamination from smelting activities, but otherwise exhibit minimal human disturbance. “Untreated mine waste” includes sites with various mine and mill waste products as the primary substrate where no revegetation efforts have occurred and with minimal recent disturbance of the mine waste. “Remediated mine waste” includes sites on chat, tailings, or both that have been treated as part of USEPA-mandated remediation efforts. “Revegetated mine waste” includes sites on chat, tailings, or both that have been revegetated for reasons other than USEPA-mandated remediation.

Old Lead Belt

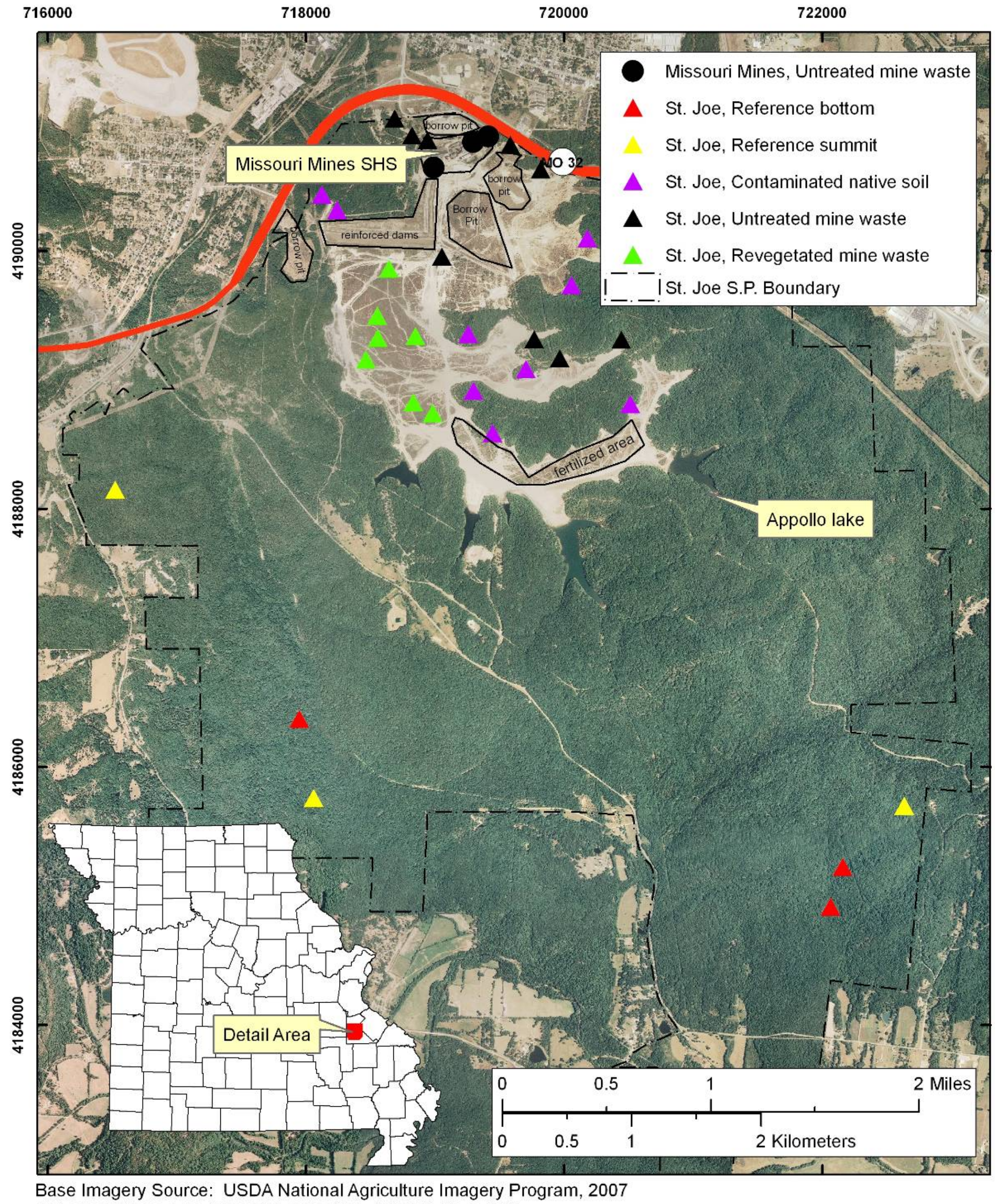
St. Joe State Park/Missouri Mines State Historic Site

St. Joe State Park (St. Joe SP) contains the Federal Mine/Mill Complex and Missouri Mines State Historic Site (Missouri Mines SHS), including buildings from what was once the largest Pb mining and milling operation in the world (Figure 2). In 1972, the St. Joe Minerals Corporation ceased operations and in 1975 donated the 3,336 ha tract containing the mine, mill and associated tailings pile to the state of Missouri. The area became a state park in 1976, and 10 ha of land and historic buildings became Missouri Mines SHS in 1980. Together, the state park and historic site include an estimated 457 ha of tailings and 13 ha of chat (USFWS 2008). The rest of the state park is primarily forest and woodlands. Of the Old Lead Belt sites selected for this study, St. Joe SP had previously been shown to have the lowest mean soil concentrations of Pb (885 mg/kg), Cd (6.5 mg/kg) and Zn (293 mg/kg; USFWS 2008).

Between 1972 and 1976, efforts were made to revegetate most of the tailings impoundments within the state park by planting a mixture of seeds, including some native seed (Figure 2). In the 1980s, dry pellet fertilizer was applied to seeded areas at the southern end of the tailings pile near Apollo Lake. In 1998, work was completed to stabilize the dams of the tailings impoundment. The front surfaces of the dams were regraded and reinforced with tailings and other mine waste taken from borrow pits at various park locations. Reinforced areas and borrow pits were also capped, planted, and fertilized to control wind and water erosion (Bonnell 2009). Biosolids from municipal waste were added to a few locations.

Due to the significance of the historic resources at Missouri Mines SHS, little has been done to either control erosion of tailings or to manage vegetation. Periodically, cedar trees (*Juniperus virginiana*) have been removed to maintain sightlines and to protect buildings and other historic resources. These areas are evident due to the presence of cut stumps. A small area in the eastern portion of the site was seeded, including some native plant species, within the last decade (Hebrank 2008).

The St. Joe SP study site included plots representing communities on 1) untreated mine waste, 2) revegetated mine waste, 3) contaminated native soils, 4) reference summits, and 5) reference bottoms. Missouri Mines SHS was included to represent untreated mine waste (revegetated areas were not sampled). The approximate bounding coordinates for the sampling area at St. Joe SP and Missouri Mines SHS are 716400E, 4184900N by 722700E, 4191100N (UTM, NAD 83 Zone 15N).



Base Imagery Source: USDA National Agriculture Imagery Program, 2007
Universal Transverse Mercator projection, NAD83, Zone 15N

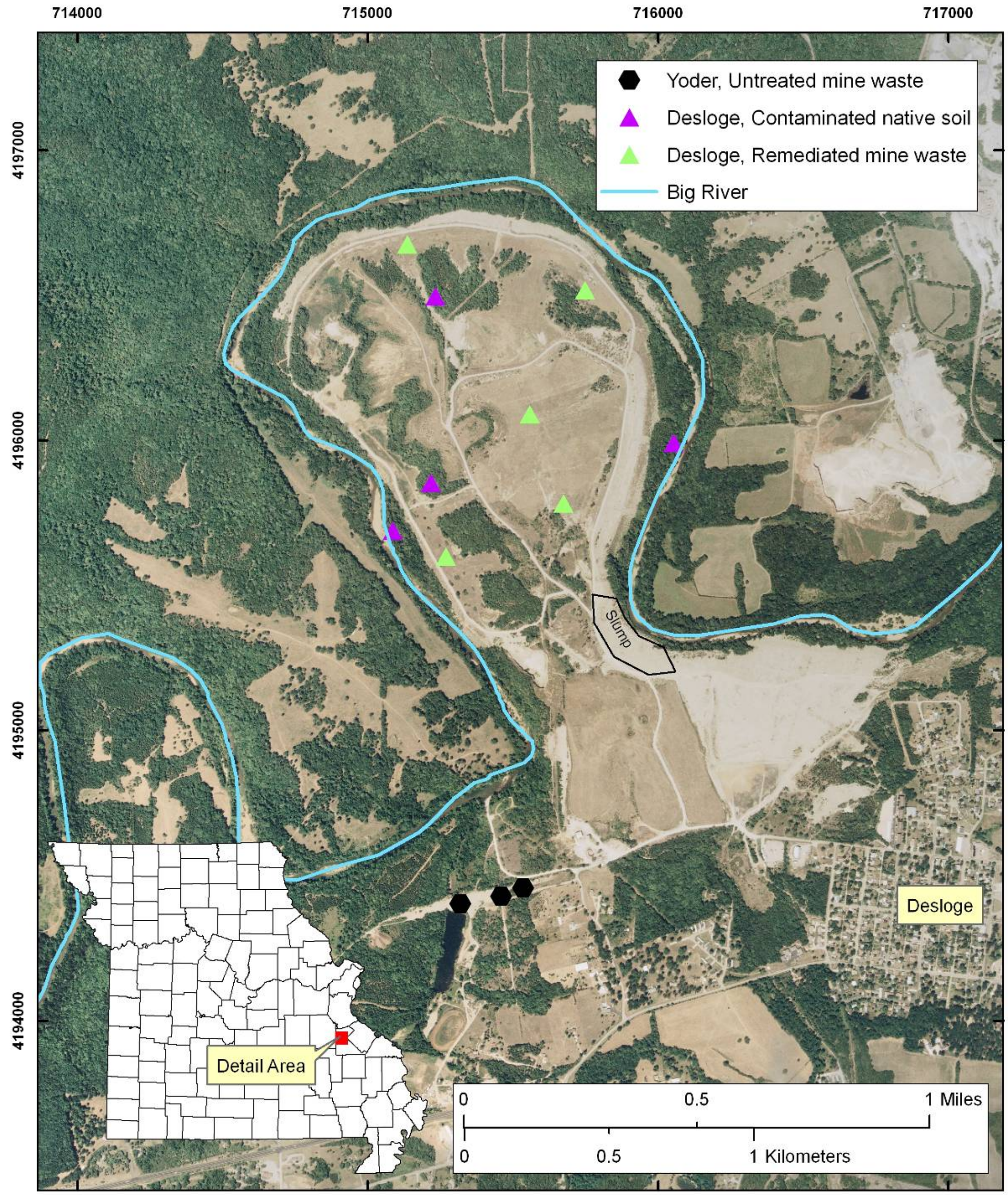
Figure 2. Sampling locations at St. Joe State Park and Missouri Mines State Historic Site, St. Francois County, Missouri.

Desloge/Yoder

The Desloge tailings pile occupies approximately 243 ha within a large bend of the Big River west of Park Hills, Missouri (Figure 3). Thirty years of mining activity ceased at Desloge in 1958 (Missouri Department of Health 1996). Tailings were deposited on the site to a maximum depth of 30 m. Average soil concentrations previously found for Pb (2,105 mg/kg), Cd (26.3 mg/kg) and Zn (1,243 mg/kg; USFWS 2008) at Desloge are moderate compared to other Old Lead Belt sites included in this study.

In 1977, approximately 38,000 m^3 of tailings on the southeast side of the pile slumped into the Big River (Missouri Department of Health 1996). In 1995, remediation efforts began to stabilize the pile and to cap and revegetate the surface of the pile "to control wind and weather erosion and [provide] rock slope protection at the waterline to prevent undercutting by the river" (USEPA 2009). Revegetation consisted of planting pasture grass seed—primarily tall fescue (*Festuca arundinacea*), with wheat (*Triticum spp.*) and oats (*Avena spp.*) planted as protective cover crops (Nations 2009). Nutrients have been augmented via applications of fertilizer, municipal waste, sludge, and/or portable toilet waste (Nations 2009, Campbell 2009). The Desloge study site includes plots representing communities on remediated mine waste and communities on contaminated native soil adjacent to the tailings pile. The bounding coordinates of the site are approximately 714600E, 4194500N by 717000E, 4197000N (UTM, NAD 83 Zone 15N).

The Yoder site includes an old railroad grade constructed of chat, tailings associated with and surrounding an impoundment, and other chat (Figure 3). The rail bed was part of the Mississippi River and Bonne Terre Railroad, built by the St. Joe Mining Co. (The Leadbelt News, 1938), and the source for materials was likely the Desloge site. All sampling was limited to the rail bed. No efforts at remediation or revegetation have occurred on tailings or chat at the Yoder site. The Yoder study site was included to represent untreated mine waste. The approximate bounding coordinates for the sampled area of the Yoder site are 715300E, 4194300N by 715600E, 4194500N (UTM, NAD 83 Zone 15N).



Base Imagery Source: USDA National Agriculture Imagery Program, 2007
Universal Transverse Mercator projection, NAD83, Zone 15N

Figure 3. Sampling locations at the Desloge and Yoder sites, St. Francois County, Missouri.

Leadwood

The Leadwood site, located immediately southwest of Leadwood, Missouri, includes approximately 214 ha of tailings and 14 ha of chat surrounded by hundreds of hectares of forested land (USFWS 2008; Figure 4). Mining activity at the Leadwood site began about 1894 and ceased about 1965 (USEPA 2006b). Previous sampling of mine waste at Leadwood (USFWS 2008) showed the second highest average soil concentration of Zn (4,691 mg/kg) and the highest average soil concentration of Cd (250 mg/kg of the Old Lead Belt sites sampled for this study. The mean Pb soil concentration (2,382 mg/kg) was moderate compared to other study sites (USFWS 2008).

According to representatives of the Doe Run Company, revegetation efforts at Leadwood began in the early 1970s. Areas were seeded with pasture grasses, mostly tall fescue. Biosolids and fertilizers have been applied sporadically since then (Campbell 2009, Nations 2009). More recent USEPA-mandated remediation activity included regrading and planting the tailings dams at the north end of the site to stabilize the tailings; regrading the highest portion of the chat pile in the central portion of the site; and capping and seeding the tailings impoundment surface. Much of this work is ongoing (Campbell 2009, Nations 2009). The Leadwood study site includes plots representing plant communities on untreated mine waste, revegetated mine waste, and contaminated native soil sites. The approximate bounding coordinates for the sampling area at Leadwood are 710200E, 4190500N by 711700E, 4193400N (UTM, NAD 83 Zone 15N).

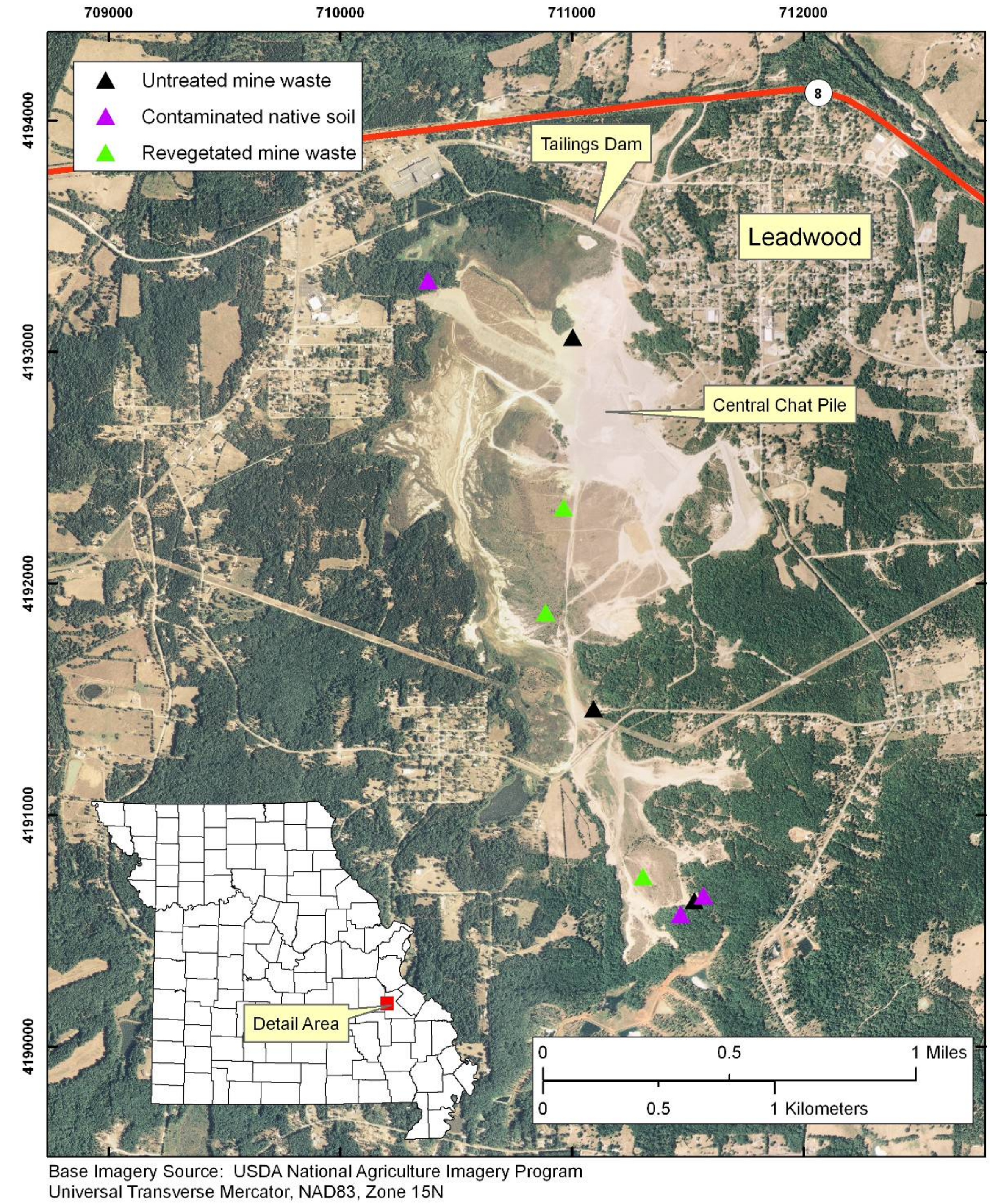


Figure 4. Sampling locations at the Leadwood site, St. Francois County, Missouri.

Elvins

Large-scale mining and milling operations began at the Elvins (Rivermines) site at the start of the twentieth century and continued until the mill closed in about 1940 (Missouri Department of Health and Senior Services 2004; Figure 5). Prior to recent USEPA-mandated remediation activities, the Elvins site was, by volume, the largest of the mine waste piles in the Old Lead Belt, with more than 7.6 million m^3 of tailings and chat (USFWS 2008). This was divided into a 53 ha tailings impoundment in the northern portion of the site, and a 52 m tall chat pile covering approximately 8 ha (Missouri Department of Health and Senior Services 2004).

In terms of mean metals concentrations, Elvins had been shown previously to have the highest soil concentration of Pb (4,400 mg/kg) and Zn (5,541 mg/kg), and the second highest soil concentration of Cd (105 mg/kg) among our study sites (USFWS 2008). The recent remediation activity affected nearly all of the Elvins pile, causing most of it to fail to meet our sampling criteria for undisturbed untreated mine waste and remediated mine waste. However, we sampled adjacent to the Elvins pile to represent vegetation communities on contaminated native soil. The approximate bounding coordinates for the sampled area at Elvins are 716700E, 4191300N by 717300E, 4191000N (UTM, NAD 83 Zone 15N).

National

Among the sites sampled in the Old Lead Belt, mining activities ceased earliest at the National pile, stopping in 1936 when operations at the mill were terminated (USEPA 2005c; Figure 5). In 2008, the remnant waste left behind by these operations was estimated at about 5 million m^3, most of which was 8 million metric tons of chat spread over 18 ha. The tailings were spread over 44 ha, in the northern and eastern portions of the site (USFWS 2008). Among our sampled sites, the waste at National had been shown previously to have the second highest soil concentration of Pb (3,661 mg/kg), with relatively low soil concentrations of Cd (7.9 mg/kg) and Zn (417 mg/kg; USFWS 2008).

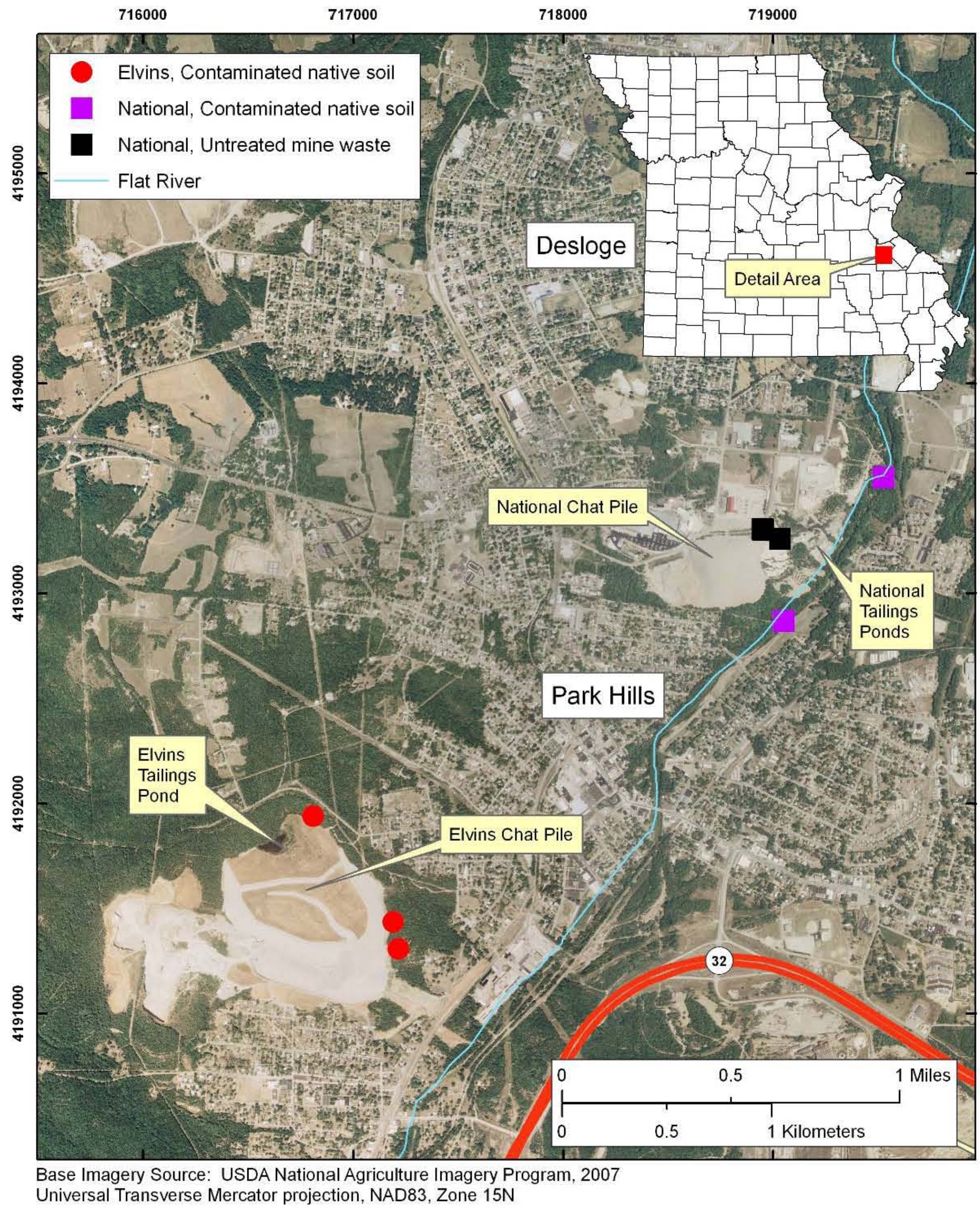


Figure 5. Sampling locations at the Elvins and National sites, St. Francois County, Missouri.

The National site is bounded on the east/southeast by Flat River, by residential property to the south, and by industrial development to the west and north. The Park Hills Chamber of Commerce owns much of the area formerly occupied by the tailings impoundments.

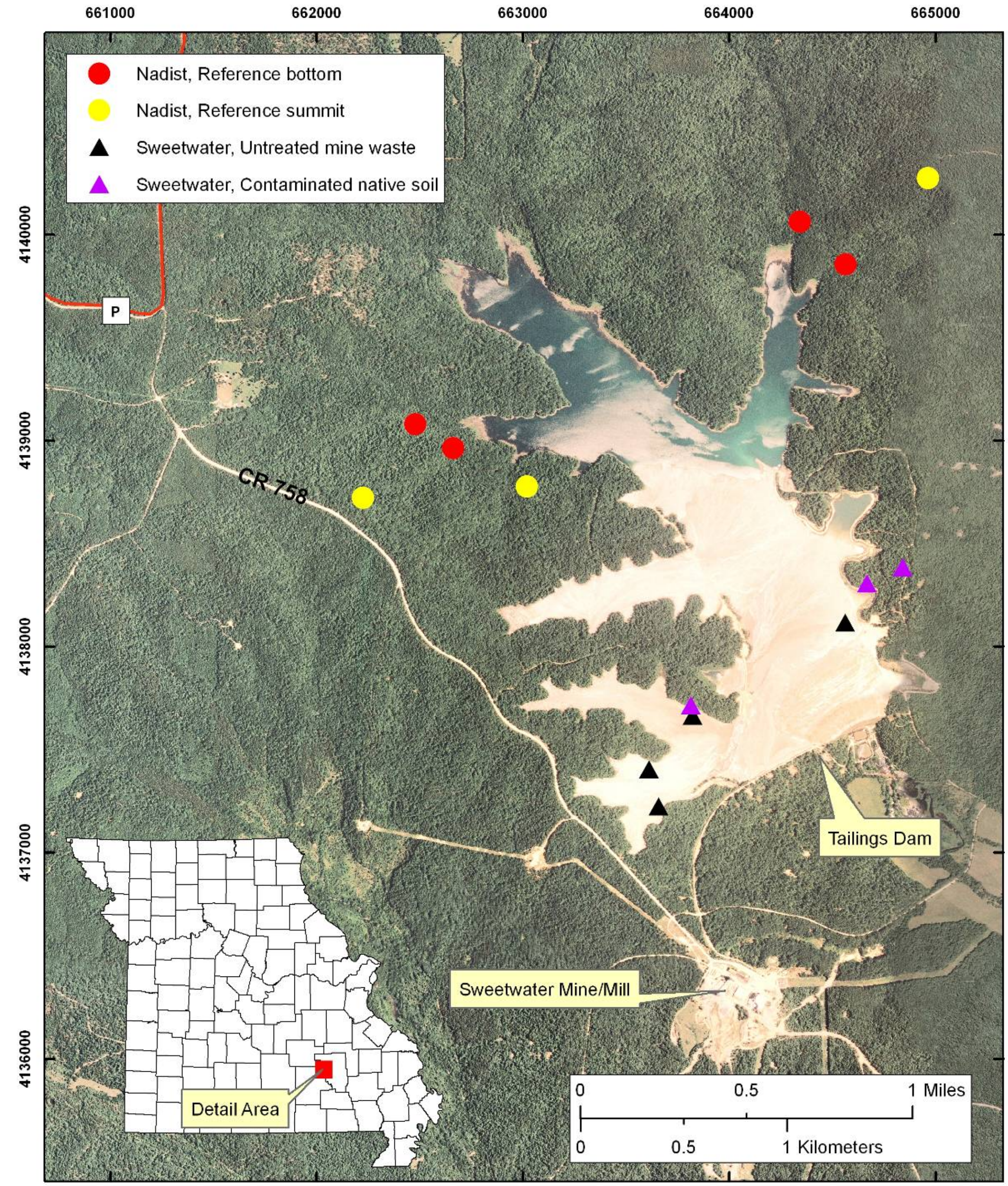
At the time of sampling, work had commenced to fulfill USEPA-mandated remediation goals. This work included regrading and stabilizing the main chat pile. As a result of these actions, large areas of the site did not meet our sampling criteria for undisturbed mine waste. However, we were able to find sample points on the chat and tailings that had not yet been modified. These were used to represent untreated mine waste, and sample points adjacent to the mine waste were selected to represent vegetation communities on contaminated native soils. The approximate bounding coordinates for the National site are 718408E, 4192866N by 719521E, 4193854N (UTM, NAD 83 Zone 15N).

Viburnum Trend

Mean metal concentrations for Viburnum Trend sites were not included in the USFWS (2008) assessment and so are not provided here.

Nadist

The Nadist site was selected to represent reference summits and bottoms for the Viburnum Trend (Figure 6). The Nadist holdings interface with the Sweetwater Mine and Mill complex via numerous surface and mineral rights easements. Currently, the Nadist properties are managed for timber, but relatively undisturbed areas were suitable for sampling. The approximate bounding coordinates of the sampling area for the Nadist site are 662200E, 4138700N by 665000E, 4140300N (UTM, NAD 83 Zone 15N).



Base Imagery Source: USDA National Agricultural Imagery Program, 2007
Universal Transverse Mercator projection, NAD83, Zone 15N

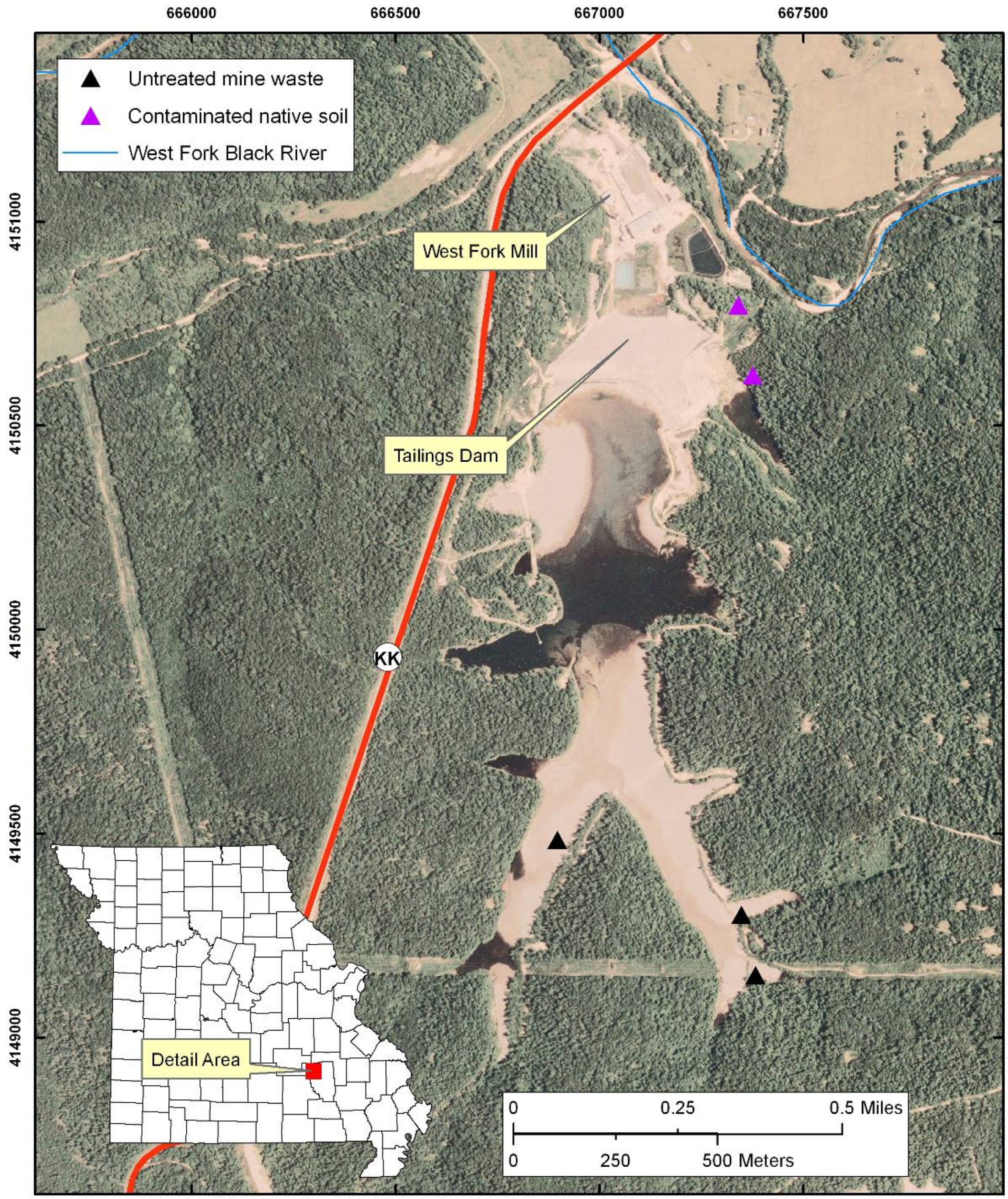
Figure 6. Sampling locations at the Nadist and Sweetwater sites, Reynolds County, Missouri.

Sweetwater

The Sweetwater Mine and Mill complex includes an active mine and mill, an associated valley-fill tailings impoundment, and forested lands around the impoundment (Figure 6). The impoundment covers approximately 245 ha. Much of the surrounding land was harvested for timber in the late 1990's when the former owner, American Smelting and Refining Company (ASARCO), liquidated its mine holdings in Missouri (Miller 2008, Murphy 2008). The Sweetwater study site included plots representing vegetation communities growing on untreated mine waste and those growing on contaminated native soil adjacent to mine waste. The approximate bounding coordinates for the Sweetwater complex are 662100E, 4136600N by 665000E, 4140300N (UTM, NAD 83 Zone 15N).

West Fork

West Fork is a functional mine and mill complex located in the Viburnum Trend (Figure 7). Mining and milling operations at the site have been temporarily suspended by The Doe Run Company. West Fork includes a valley-fill tailings impoundment covering approximately 57 ha as well as forested lands around the pond. Like Sweetwater, much of the surrounding lands were harvested for timber in the late 1990s when ASARCO liquidated its mine holdings in Missouri (Miller 2008, Murphy 2008). The West Fork study site included plots representing vegetation communities on untreated mine waste and those on contaminated native soils adjacent to mining sites. The approximate bounding coordinates of the West Fork site are 666150E, 4148800N by 667600E, 4151300N (UTM, NAD 83 Zone 15N).



Base Imagery Source: USDA National Agriculture Imagery Program, 2007
Universal Transverse Mercator projection, NAD83, Zone 15N

Figure 7. Sampling locations at the West Fork site, Reynolds County, Missouri.

Glover Smelter

The Glover Smelter site is unique in that it is our only study site representing vegetation communities growing on native soils contaminated by smelting activities (Figure 8). Smelting activities at Glover were suspended in 2003. The smelter is located at approximately 704118E, 4150986N, but sampling was limited to an area in the dominant downwind direction from (east/northeast; University of Missouri AgEBB 2008) and within 1.2 km of the smelter (704250E, 4150800N by 704700E, 4152200N; UTM, NAD 83 Zone 15N). Like Sweetwater and West Fork, much of the surrounding lands were harvested for timber in the late 1990s when ASARCO liquidated its mine holdings in Missouri (Miller 2008, Murphy 2008).

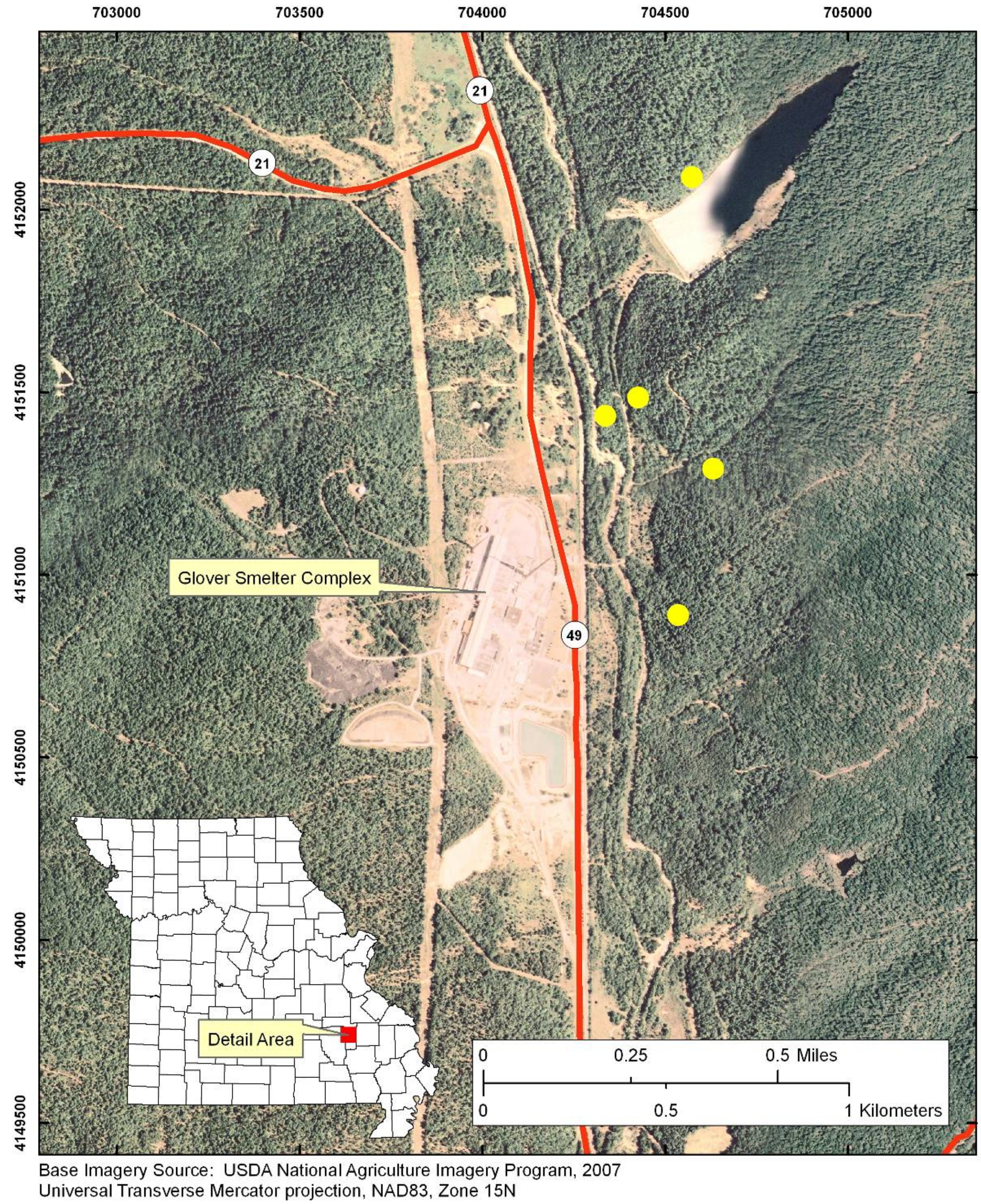


Figure 8. Smelter contaminated sampling locations at Glover, Iron County, MO.

Methods

Data Collection

Plot Selection

At all study sites, we relied on the expertise of site managers and other representatives of the appropriate administrative entity to identify general areas both likely and unlikely to meet our sampling criteria. For sites in the Old Lead Belt, we also used an aerial photo analysis conducted by the USEPA (1989). This analysis included photos of each of the Old Lead Belt sites from 1937, 1954, 1964, 1971, 1978, 1984 and 1989 and delineated broad areas where various management activities occurred. This was a critical tool for determining whether sites had been revegetated or otherwise treated, particularly at St. Joe State Park. Once an area was determined to be acceptable, final plot location was randomized within the usable area.

We generated random points within identified sampling areas and identified each in advance as a potential specific site type (reference summit, reference bottom, contaminated native soil, smelter contaminated native soil, untreated mine/mill waste, remediated mine/mill waste or revegetated mine/mill waste). We located the points in the field and then confirmed or rejected each point as suitable for sampling as its site type; we did not reclassify points that failed to meet the sampling criteria for one site type into another site type. To confirm or reject points, we used the following criteria:

1. Pb surface soil concentration determined by a hand-held X-Ray Flourometer (XRF)
2. No logging activity for at least 50 years
3. No grazing for at least 30 years
4. No roads, trails, or other evidence of human disturbance

Additional sources of information were used to determine whether a point met our sampling criteria. Points provisionally identified as contaminated native soils had to have no visible signs of tailings deposition and a mean surface soil Pb concentration exceeding an average of 100 mg/kg from three XRF readings. Contaminated native soil plots had the additional criterion of being within 60 m of the tailings pile, but local all terrain vehicle (ATV) use or recent logging required that we move the plot farther from mine waste in a few instances. Earlier research in the Old Lead Belt had documented elevated concentrations of Pb, Cd and Zn up to 300 m from tailings and chat (USEPA 2006a). We accepted this 300 m distance as a secondary distance defining transition soils and all contaminated soil plots were well within this distance from mine waste. Reference sites required an average surface soil Pb concentration of less than 100 mg/kg from three XRF readings. All sites were visually inspected for signs of ATV use or other anthropogenic disturbances not related to mining that could affect vegetation. Evidence of such activities precluded sampling only if there was evidence of vegetation disturbance in the immediate sampling area. For example, we specifically avoided well established ATV trails, but a sampling location with a single, aberrant ATV track through it could be sampled if there was no evidence of vegetation change associated with that track. Similarly, a plot could be located in a forest that had been harvested for timber if there was neither visible evidence of harvest in the immediate sampling area nor any vegetation changes determined to be an effect of harvest activities.

Plot Location

If a point was determined to be acceptable, we used the randomly identified point as the southwest corner of the sampling plot. We recorded the location of the southwest corner of each plot using a Magellan (Thales) ProMark 3 GPS receiver with an external NAP100 antenna configured to collect readings using the Universal Traverse Mercator (UTM) coordinate system and referenced to the North American Datum 1983 (NAD83), Zone 15N. Position data were collected every second for a minimum of 10 minutes at each plot, and then post-processed against NOAA-National Geodetic Survey Continually Operating Reference Station (http://www.ngs.noaa.gov/CORS/Data.html) data using the Magellan Mobile Mapper Office Software. This system generates sub-meter post-processed horizontal accuracy. Data were exported as 3-D shapefiles (.shp). Each plot was photographed from the southwest corner toward the northeast corner. Plots measured 20 m x 20 m (400 m^2), with edges laid out in cardinal directions. If necessary, plots were reoriented and reshaped (retaining the 400 m^2 search area) in order to remain within a given site type or landform.

Vegetation Sampling

We adapted methods from the U.S. National Vegetation Classification System (USNVC) to sample vegetation communities. The USNVC is the standard for mapping vegetation communities on Federal lands (USNVC; The Nature Conservancy 1994). Within the USNVC system, each vegetation stratum (emergent canopy, canopy, subcanopy, tall shrub, short shrub and groundflora) is sampled separately. Because the USNVC methodology provides greater resolution than required for this project and we were limited in the amount of time available for sampling, we combined the six strata above into three strata: 1) canopy/subcanopy (includes USNVC emergent canopy, canopy and subcanopy), 2) shrub/sapling (includes USNVC shrub layers and saplings under five meters), and 3) groundflora. Within each stratum, we identified each species present in the plot and estimated its percent cover to the nearest one percent based upon a vertical projection of foliar cover, following methods described by Daubenmire (1959). Nomenclature followed the USDA PLANTS database (USDA-NRCS 2008).

Species that we were unable to identify in the field were assigned a code, described for future reference and collected for later identification. Similarly, we noted any plants with uncertain identification and collected them for later confirmation of the field identification. Our primary references for plant identification were *Flora of Missouri* (Steyermark 1963), and *Steyermark's Flora of Missouri Volume 1* (Yatskievych 1999) and *Volume 2* (Yatskievych 2006). All collected specimens were compared against reference specimens in both the USGS Columbia Environmental Research Center herbarium and the Missouri Botanical Garden reference collection for the Flora of Missouri Project. Identifications of most collected specimens were confirmed with the author of the revised *Flora of Missouri* (Yatskievych 2008).

All plot data were collected using the EcoNab data collection tool developed by the National Institute of Invasive Species Science (NIISS 2007) on handheld electronic data collection devices with the Palm™ operating system. Data were downloaded to and managed within the VegSurvey Database (.mdb format), also available from the NIISS website. Together, these programs include numerous features designed to ensure data quality, including required-entry data fields, a subprogram to aid in the management and identification of unknown species, and regionally customizable look-up tables for species.

Environmental Data

We collected data on a standard set of environmental variables. These included slope degrees, slope aspect, and the percent cover of 1) bare soil, 2) leaf litter and dead herbaceous matter, 3) woody debris, 4) tree roots and basal area and 5) native rock. We also estimated the total percent cover of vegetation in each of the groundflora, shrub/sapling, and canopy/subcanopy layers to the nearest one percent.

Soil Sampling

At each plot, we collected soil from three areas representing the approximate locations of the southwest corner, the plot center, and the northeast corner. We used a tempered steel shovel to expose topsoil (0 to 20 cm) and subsoil (20-35 cm). The MDNR (2001) and USEPA (2003b) guidelines for soil sampling for Pb contamination on residential sites allows for the use of metallic sampling devices, including spades, shovels, trowels and mixing bowls. We then cleaned the exposed soil surfaces with a plastic scoop to expose soils that had not come in contact with the shovel. A clean plastic scoop was used to excavate laterally into the sides of the hole and remove samples from the unexposed soil surfaces. Sampling scoops were cleaned with a plastic brush and deionized water between all soil samples.

Topsoil and subsoil samples from all three pits in the plot were combined in separate plastic sealable bags, which were labeled with the following information: study name, sample number, collector, date, time, site, plot, and soil layer. Soil samples were transferred to the Missouri Department of Natural Resources to be analyzed for the presence of metals using X-ray Flourometry (MDNR 2008). For quality control purposes, MDNR sent ten percent of the XRF samples to a secondary MDNR laboratory for analysis of metals concentrations by inductively-coupled plasma emission mass spectrometry (ICPMS; MDNR 2005, 2006 and 2007). The MDNR also sent all soil samples to the University of Missouri Extension for soil nutrient and other analyses. Data returned from soil analyses included soil organic matter, extractable soil phosphorus (P), calcium (Ca), magnesium (Mg) and potassium (K), soil pH in salt solution (pH), neutralizable acidity (NA), and cation exchange capacity (CEC; Nathan and others 2006).

Data Analysis

Overview

We used multiple analytical techniques to assess the relationship between metals concentration, soil nutrients, other soil characteristics and floristic quality. Our first step was to determine which environmental variables were most strongly associated with floristic quality measures. To accomplish this, we used two multivariate techniques—Non-metric Multidimensional Scaling and Regression Tree Analysis—to assess the nature and strength of the relationships of metals concentrations and other soil variables to measures of floristic quality. We also tested for differences in floristic quality measures between *a priori* site types using Analysis of Variance.

The *a priori* site types were a somewhat arbitrary classification. Within plots located on native soils, some locations classified in the field as "contaminated" based upon field XRF readings of Pb concentration were demonstrated to have concentrations below 100 mg/kg during subsequent laboratory XRF analysis of dried and processed samples. The converse was true for some sites classified as "reference" in the field. Thus, there was overlap between reference sites and contaminated sites in terms of Pb concentrations. In addition, site classification based on surface soil XRF readings did not reflect subsoil concentrations, which can be important for plants. We also recognized that "remediated" and "revegetated" mine waste sites differed in time since treatment (some sites had been revegetated more than 30 years ago, while others have been treated in the last decade) and in the seed mixtures used. Furthermore, sites differed in the quantities and types of soil amendments used. Differences in biosolid quantity can directly affect plant communities by altering the amount of nutrients available. Differences in biosolid quality can alter the fate and bioavailability and plant uptake of lead, cadmium and zinc (Brown and others 1995, 2005).

Given these confounding conditions, we complemented means tests based on *a priori* site types with means tests between contamination classes based on recognized, biologically relevant thresholds as suggested by Eco-SSLs. We also described the relationships between Pb and Zn concentration and floristic quality measures on native soils and on untreated mine waste using univariate least squares linear regression.

Floristic Quality Metrics

Following Swink and Wilhelm (1994) and using C values for Missouri flora (Ladd 1993), we used presence/absence data to calculate Mean C and the Floristic Quality Index (FQI) for each plot. For each *a priori* site type (reference summit, reference bottom, contaminated native soils, contaminated mine/mill waste, smelter site, remediated mine waste and revegetated mine waste), we calculated the average Mean C and mean FQI.

Nonmetric Multidimentional Scaling Ordination

The ordination technique Nonmetric Multidimensional Scaling (NMS) was used to understand and display differences in community composition between *a priori* site types and the environmental factors that may be driving those differences. It is an iterative process to find the best fit of data in a reduced number of dimensions. Unlike other ordination techniques, NMS does not yield a single unique solution, and subsequent NMS analysis using the same data set and the same parameters can yield a slightly different result. Analysis using NMS has an advantage over other ordination techniques in that it 1) makes no assumption about the normality of data sets, 2) allows users to examine the final data structure in relation to environmental variables (whether independent or dependent), and 3) does not constrain the data structure within a predefined set of variables (McCune and Grace 2002). According to McCune and Grace (2002), NMS "is the most generally effective ordination method for ecological community data." We applied NMS as a means of understanding 1) relationships between *a priori* site types and 2) the relationship of species composition and abundance to independent environmental variables and dependent vegetation measurements.

Analysis using NMS yields a measure of final stress (lack of fit) and a graphical output of plots, species, or both according to their ordination scores. The PC-ORD software (McCune and Mefford 1999) produces a stress measure with values ranging from 1 to 100. Values of less than five are ideal but rarely achieved with ecological data; values less than 10 pose little risk of misinterpretation. Values between 10 and 20 provide a worthwhile understanding of the data, but require cautious interpretation, particularly at the high end (Kruskal 1964, Clark 1993 *in* McCune and Grace 2002). Unlike eigenvalue-eigenvector ordination techniques (such as principal components analysis or correspondence analysis), NMS does not align the data so that Axis 1 explains most of the variation in the data. In fact, in NMS "there is no such thing as a correct rotational position for the configuration" (Kruskal and Wise 1984). Thus, it is not necessarily the case that Axis 1 will explain most of the variation and graphs can be rotated without changing the distance between points or the cumulative variance represented by the axes being rotated (McCune and Grace 2002).

When considering the NMS graphical output, the proximity of plots to one another reflects their similarity in terms of species composition and abundance. The percent of variation explained by each axis can be assessed from its Pearson's r^2 value. It is reasonable to interpret ordination in which two axes explain 30-50 percent of the variation, while ordinations with more than 50 percent of the variation explained by two axes are considered quite dependable aids to interpretation (McCune and Grace 2002). Additionally, a correlation vector between each environmental variable and community composition can be displayed as a line. The direction of the line from the ordination center (0,0) indicates the direction of increase for that variable. The length of the line is proportional to the r^2 values of the variable with respect to the axes and reflects the strength of the relations.

For NMS analysis, each species record was first converted to a stratum-specific record by appending a stratum code as a prefix to the species code. As a result, a species such as *Acer rubrum* (code=acru) that is found in the ground flora (g) at one percent cover and in the shrub/sapling (s) layer at five percent cover would occur as separate species in the ordination matrix; "g-acru" and "s-acru", with cover values of one and five, respectively. This data-conversion technique is advantageous in that it retains all of the information concerning plot-specific vegetation structure and allows for simultaneous analysis of data from multiple vegetative strata. Cover values were then log-transformed before being analyzed using the Sorensen (Bray-Curtis) distance measure and the "Slow and Thorough" autopilot setting in PC-ORD v. 5.0 (McCune and Mefford 1999). The specific parameters for this method are shown in Table 1. Although rotating the graph does not change the cumulative variation explained by the axes, it does change the amount of variation explained by individual axes (McCune and Grace, 2002). Therefore, to simplify interpretation, NMS graphs have not been rotated. Also to simplify interpretation, NMS outputs have been displayed with only two axes, even when a three dimensional solution was reached.

Table 1. Settings for NMS parameters in the “Slow and Thorough” autopilot mode in PC-ORD v 5.0 (McCune and Mefford 1999).

Parameter	Setting
Maximum number of iterations	400
Instability criterion	0.00001
Starting number of axes	6
Number of real runs	40
Number of randomized runs (for Monte Carlo test)	50

Regression Tree Analysis

As an alternative explanation of vegetation metrics without regard to our *a priori* site types, we used least squares regression trees to explore which variables best explain variation in Mean C and FQI and to resolve possible subjectivity of classifying sites into artificial groups. Regression tree models use nonparametric, recursive methods to partition datasets into increasingly homogeneous subgroups with respect to the response variable (Breiman and others 1984). Regression trees are appropriate for determining which environmental variables explain differences in species composition or community metrics; as recursive models, they can capture relationships that are difficult to reconcile with conventional univariate or multivariate linear models (Urban 2002). These models are particularly useful in situations where effects of predictor variables are non-additive, or when predictor variable interactions are not simply multiplicative (Urban 2002). Regression trees are also valuable data mining tools; the most relevant independent variables are chosen to partition the response variable at separate nodes (Venables and Ripley 1994); the structure of the resulting tree provides insight into the predictive structure of the independent variables (Breiman and others 1984). In this study, interactions between multiple variables describing metal concentration, nutrients and other soil characteristics in two soil layers become too complex to interpret in ANOVA tables, but they can become clear in the graphic display of the regression tree. Tree-structured regression is robust with respect to measurement variables, but can be highly influenced by unusually high or low response variable values (Breiman and others 1984). However, the tree can treat such values in a way that both minimizes their effect and notes their presence by isolating them in a node, which makes this approach less subject to distortion than univariate linear regression (Breiman and others 1984). To identify the primary variables explaining variation in Mean C and FQI, we limited the trees to three splits with a minimum of two plots per cluster. Keeping the number of plots per cluster as low as possible allows the model to best identify extreme values at any given node.

Means Testing

We tested for differences in floristic quality measures between the *a priori* site types using Analysis of Variance with *post hoc* Tukey Multiple Comparison tests. We also used the Eco-SSL of 120 mg/kg for Pb (USEPA, 2005b) to test for differences in average Mean C and FQI between plots with metals concentrations above the Eco-SSL and those below. We used a t-test assuming unequal variance ($\alpha = 0.05$) using SYSTAT v. 11 (Systat Software, Inc. 2004). Comparisons were made between Eco-SSL classes using topsoil, subsoil, and average soil concentrations of Pb.

Earlier work in the study area (USEPA 2006a; USFWS 2008) used 50 mg/kg as the Eco-SSL for Zn based on earlier published values (USEPA 2003a), while expert opinion based on extensive literature review cites 70 mg/kg as the low threshold for phytotoxic effects of Zn in the Old Lead Belt region (Kaputska 2007). We used the current Eco-SSL of 160 mg/kg (USEPA 2007a) and the higher of the other earlier values (70 mg/kg, Kaputska, 2007) to partition Zn data into three response classes. We used Analysis of Variance (ANOVA) with *post-hoc* Tukey HSD Multiple Comparison tests using SYSTAT v. 11 (Systat Software, Inc. 2004) to test for differences in average values for Mean C and FQI among plots in the three Zn classes for topsoil, subsoil and averaged soil Zn concentrations.

Univariate Regression

We ln-transformed Pb and Zn concentration data, an appropriate technique to make data sets with asymmetrically high values more symmetric (Moore and McCabe 1989). We used univariate least squares linear regression of Mean C and FQI against transformed Pb and Zn concentrations in the topsoil, subsoil and averaged between subsoil and topsoil using SYSTAT v. 11 (Systat Software, Inc. 2004). Using regression equations for native soil plots, we calculated concentrations of Pb and Zn at which one could expect to see reductions of 10 and 20 percent in Mean C and FQI compared to the mean value of these measures on sites with concentrations below Eco-SSLs (120 mg/kg for Pb and 160 mg/kg for Zn).

Results

Data Summary

We sampled 87 plots at 11 sites; four sites in the Viburnum Trend and at Glover, and seven sites in the Old Lead Belt. Sampling began in early June, 2008, and concluded in early September, 2008. For communities occurring on native soils, we sampled 6 reference summits, 7 reference bottoms, 26 contaminated native soil plots and 5 smelter contaminated plots. We also sampled 28 untreated mine waste plots, 5 remediated mine waste plots and 10 revegetated mine waste plots. The distribution of plots by *a priori* site type and study site is shown in Table 2. We encountered 544 plant species, of which 472 were native and 72 were non-native. An additional four species (twelve occurrences) remain unidentified and have been excluded from all analyses.

Soil Cd concentration was below the XRF detection level of 50 mg/kg (Innov-X Systems, Inc. 2007) in all but eight plots (one contaminated native soil plot, one revegetated mine waste plot and six untreated mine waste plots; Appendix I). In untreated mine waste plots with detectable Cd concentration, three had detectable Cd in the topsoil layer only, two had detectable Cd in the subsoil layer only, and one plot had detectable Cd in both soil layers. This inability to detect Cd prevented analysis of response variables to Cd concentration. Therefore, we limited our statistical analysis to Pb and Zn concentration, all readings of which exceeded the XRF detection limit of 10 mg/kg (Innov-X Systems Inc. 2007).

A summary of Pb and Zn concentrations by site type is shown in Table 3. Reference summit plots had the lowest average topsoil and subsoil Pb concentrations at 40 mg/kg and 28 mg/kg, respectively. Untreated mine waste plots had the highest average topsoil (2,712 mg/kg) and subsoil Pb (1,807 mg/kg) concentrations.   This was also true of Zn concentrations; reference summit sites had the lowest topsoil and subsoil concentrations at 33 mg/kg and 34 mg/kg, respectively; and untreated mine waste plots had the highest topsoil (810 mg/kg) and subsoil Zn (748 mg/kg) concentrations (Table 3).

Table 2. Distribution of plots by *a priori* site type across sites and sampling areas.

	Native Soils				Mine Waste			
Site	Reference Summit	Reference Bottom	Contaminated	Smelter Contaminated	Untreated	Remediated	Revegetated	Total
Old Lead Belt								
Desloge	-	-	4	-	-	5	-	**9**
Yoder	-	-	-	-	3	-	-	**3**
National	-	-	2	-	3	-	-	**5**
St. Joe	3	3	9	-	9	-	7	**31**
Missouri Mines	-	-	-	-	3	-	-	**3**
Elvins	-	-	3	-	-	-	-	**3**
Leadwood	-	-	3	-	3	-	3	**9**
Viburnum Trend/Glover								
Nadist	3	4	-	-	-	-	-	**7**
Sweetwater	-	-	3	-	4	-	-	**7**
West Fork	-	-	2	-	3	-	-	**5**
Glover	-	-	-	5	-	-	-	**5**
Overall Total	**6**	**7**	**26**	**5**	**28**	**5**	**10**	**87**

Table 3. Summary of Pb and Zn concentrations by *a priori* site type

	Lead concentration (mg/kg)						Zinc concentration (mg/kg)					
	Topsoil			Subsoil			Topsoil			Subsoil		
Site type	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Reference bottom	80	24	157	65	13	150	60	25	110	57	21	105
Reference summit	40	30	53	28	12	44	33	25	49	34	21	64
Contaminated native soil	510	36	3249	409	18	3679	320	36	1172	193	27	1276
Smelter contaminated soil	687	378	1413	124	84	158	124	67	225	100	67	169
Remediated mine waste	993	843	1265	828	686	1053	801	541	1329	673	243	827
Revegetated mine waste	871	525	1075	754	496	1212	562	230	974	577	213	1332
Untreated mine waste	2712	181	21707	1807	281	9579	810	71	1976	748	47	2305

Topsoil Pb and Zn concentrations on mine waste substrate plots ranged from 181 mg/kg to 21,707 mg/kg, and 71 mg/kg to 1,976 mg/kg, respectively (Table 3). Topsoil Pb and Zn concentrations on adjacent native soils ranged from 36 mg/kg to 3,249 mg/kg, and 36 mg/kg to 1,172 mg/kg, respectively (Table 3). Topsoil Pb and Zn concentrations in reference plots ranged from 24 mg/kg to 157 mg/kg, and 25 mg/kg to 109 mg/kg, respectively (Table 3). We documented a strong relationship between Pb and Zn concentrations in topsoil, subsoil and mean soil concentrations; Zn concentrations were generally lower than those for Pb (Figure 9).

Maximum concentrations of Pb in contaminated native soil sites sampled in this study were 3,679 mg/kg, exceeding maximum levels (1,540 mg/kg) found in transition zone soils in the region in 2006 (USEPA 2006a). Maximum Zn concentrations in contaminated soils in our study were 1,276 mg/kg, less than the 1,640 mg/kg found in transition soils in 2006 (USEPA 2006a). On mine waste sites, maximum concentrations of Pb and Zn were 21,707 mg/kg and 2,305 mg/kg, respectively; this exceeds maximum Pb concentrations of 17,000 mg/kg found in 2006, but not the maximum concentrations of Zn (25,800 mg/kg) found in mine waste sites in 2006 (USEPA 2006a).

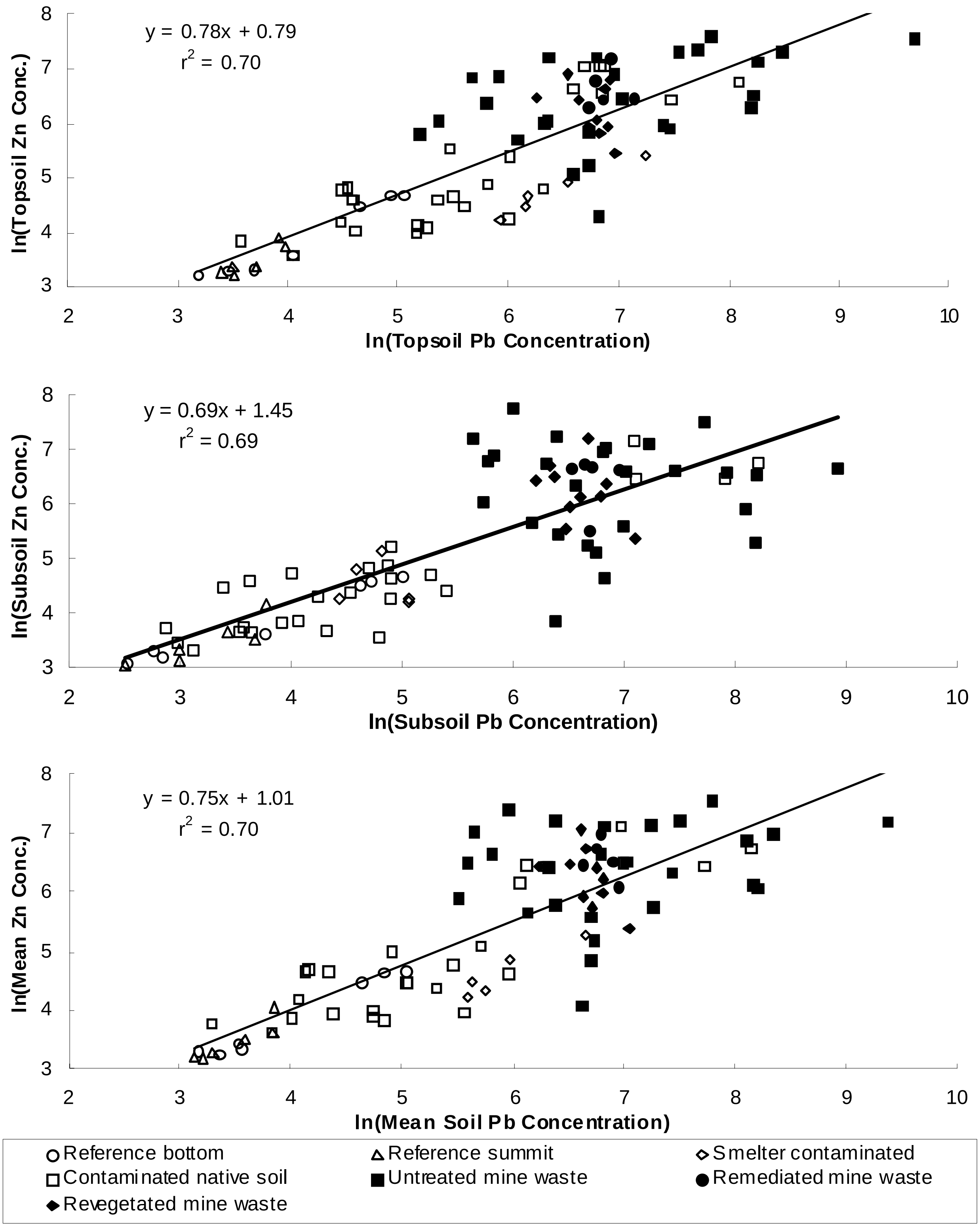


Figure 9. Regression plots of natural log (ln)-transformed Zn concentrations (mg/kg) against ln-transformed Pb concentrations (mg/kg) for all plots (n=85; $p < 0.001$).

Among native soil types, reference bottoms had an average Mean C value of 4.41 and the highest average FQI of 43.76 (Table 4). Among the remaining native soil types, reference summits had the highest average Mean C (4.63), but the lowest FQI (34.96; Table 4); contaminated native soil plots had the lowest average Mean C (4.26) and a mean FQI of 35.94 (Table 4); smelter contaminated plots had an average Mean C of 4.50 and a mean FQI of 40.38 (Table 4).

Among mine waste sites, average Mean C ranged from 2.48 (remediated mine waste) to 3.40 (revegetated mine waste; Table 4). Mean FQI values on untreated mine waste, remediated mine waste and revegetated mine waste were 9.42, 10.04 and 16.30, respectively (Table 4).

Table 4. Average Mean C and FQI by site and *a priori* site type

	Mean C							FQI						
	Native Soils				Mine Waste			Native Soils				Mine Waste		
Site	Reference Summit	Reference Bottom	Contaminated	Smelter Contaminated	Untreated	Remediated	Revegetated	Reference Summit	Reference Bottom	Contaminated	Smelter Contaminated	Untreated	Remediated	Revegetated
Old Lead Belt														
Desloge	-	-	3.93	-	-	2.48	-	-	-	35.76	-	-	10.04	-
Yoder	-	-	-	-	2.34	-	-	-	-	-	-	10.72	-	-
National	-	-	3.47	-	3.41	-	-	-	-	27.65	-	12.19	-	-
St. Joe	4.59	4.08	4.39	-	2.98	-	3.59	34.02	43.42	37.18	-	10.80	-	18.44
Missouri Mines	-	-	-	-	3.50	-	-	-	-	-	-	6.15	-	-
Elvins	-	-	4.26	-	-	-	-	-	-	32.95	-	-	-	-
Leadwood	-	-	4.18	-	2.99	-	2.95	-	-	33.97	-	9.89	-	11.29
Viburnum Trend/Glover														
Nadist	4.68	4.66	-	-	-	-	-	35.90	44.01	-	-	-	-	-
Sweetwater	-	-	4.62	-	3.67	-	-	-	-	39.98	-	4.50	-	-
West Fork	-	-	4.73	-	2.99	-	-	-	-	40.43	-	8.61	-	-
Glover	-	-	-	4.50	-	-	-	-	-	-	40.38	-	-	-
Overall Mean	**4.63**	**4.41**	**4.26**	**4.50**	**3.10**	**2.48**	**3.40**	**34.96**	**43.76**	**35.94**	**40.38**	**9.42**	**10.04**	**16.30**

NMS Ordination

All Plots

Analysis of the complete data set using NMS yields a three-dimensional solution with a final stress of 12.4 ($p = 0.004$; Figure 10). Axis 1 and Axis 2 explain 31 and 33 percent of the variation, respectively, while Axis 3 (not shown) explains 18 percent of the variation. Those variables having the greatest correlation with the ordination all relate to the richness and abundance of native species: native species cover ($r^2 = 0.79$), FQI ($r^2 = 0.78$), overall richness ($r^2 = 0.73$) and native species richness ($r^2 = 0.73$; Table 5). All of these values increase toward the upper right of the graph, toward native soils plots. The independent variable most closely correlated to community composition is topsoil K ($r^2 = 0.54$; Table 5). The metals measurement with the greatest correlation to community composition is subsoil Zn ($r^2 = 0.47$; Table 5), which increases toward the lower left of the graph. The graphical display shows a clear distinction between those plots (contaminated and reference) located on intact native soils and those plots on mine waste (treated and untreated). The output also shows a strong distinction between untreated mine waste and both remediated mine waste and revegetated mine waste. Based upon these observations, we performed additional analysis on data from two subsets of plots; 1) all plots on native soils, and 2) all untreated mine waste plots.

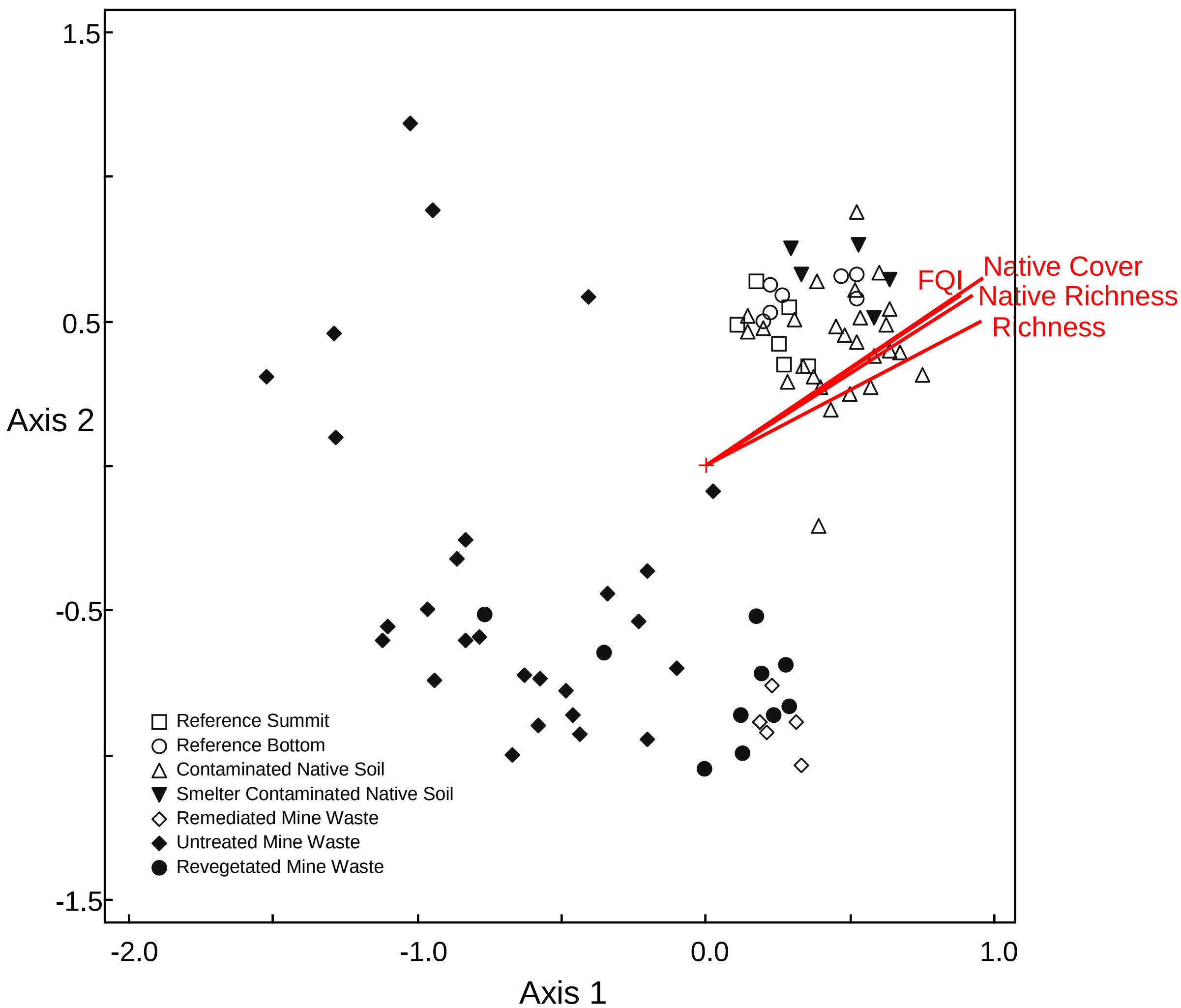


Figure 10. PC-ORD NMS output showing distribution of all plots by *a priori* site type and those variables most correlated to community composition (red lines; $r^2 > 0.70$).

Native Plots

Analysis of native soils plots using NMS yielded a two-dimensional solution with a final stress of 11.2 (p = 0.004; Figure 11). Axis 1 explains 34 percent of the variation, while Axis 2 explains 55 percent of the variation. Multiple r^2 values for all variables are given in Table 5. The variables with the strongest correlation to the overall data structure are Mean C (r^2 = 0.71), subsoil Zinc concentration (r^2 = 0.60), mean Zn concentration (r^2 = 0.53) and the ratio of exotic species richness to native species richness (r^2 = 0.51; Table 5). Among independent variables, metals concentrations correlate with community composition (r^2 > 0.35) more than do other soil variables (Table 5). Metals concentrations have positive relationships with Axis 2 and negative relationships with Mean C. The output also indicates that reference summits form a distinct group that tends to have high Mean C values and low metals concentrations. The four contaminated native soil plots (Desloge02, Desloge 10, National 4 and National 5) clustered at the top of Figure 11 are similar in their species composition and abundance and strongly influence the relationship between subsoil Zn concentration and Axis 2.

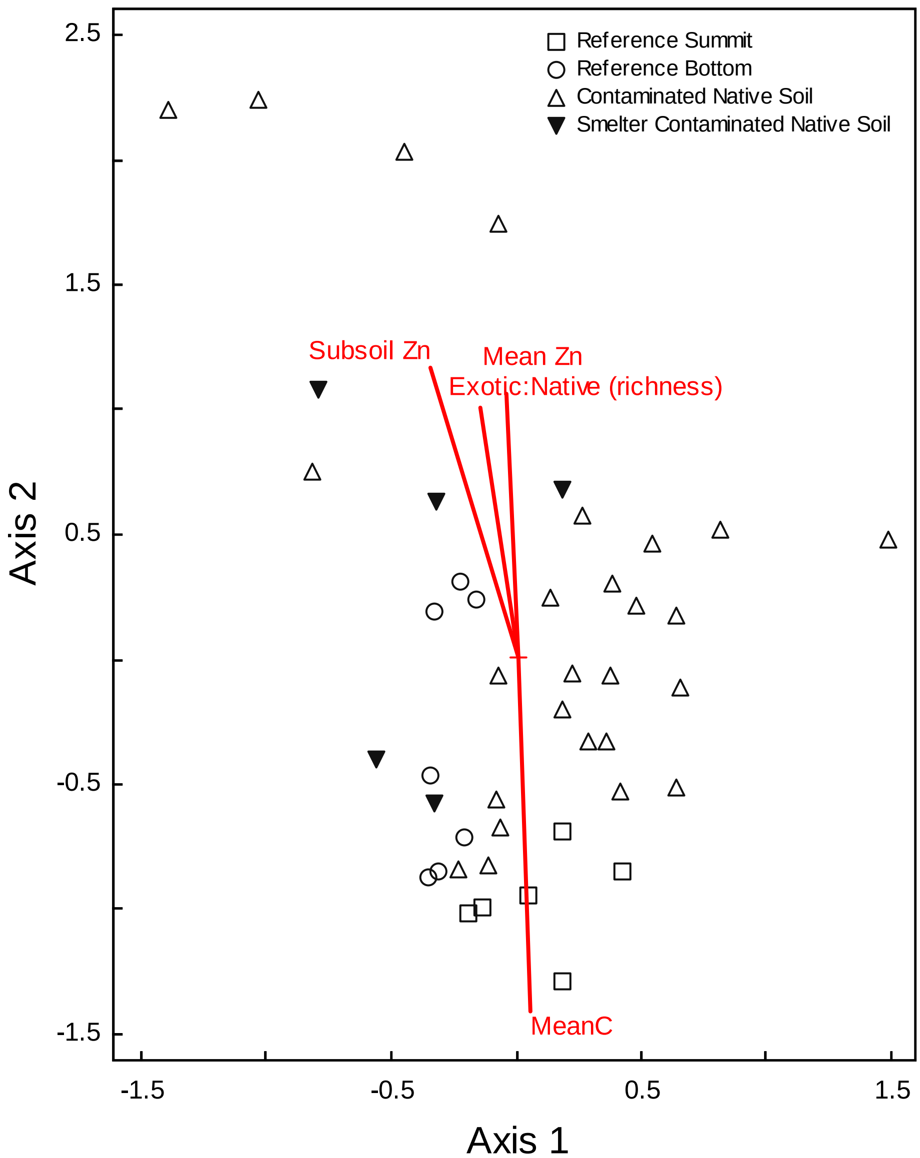


Figure 11. PC-ORD NMS output showing distribution of native soil plots by *a-priori* site type and those variables most correlated to community composition (red lines; $r^2 > 0.50$).

Mine Waste Plots

We also analyzed data from plots located on untreated waste to determine which environmental variables determine community composition in the absence of revegetation and remediation treatments. Analysis using NMS yields a three-dimensional solution with a final stress of 15.4 ($p = 0.004$; Figure 12). Axes 1, 2 and 3 represent 22, 32 and 21 percent of the variation, respectively. The distribution of plots in the ordination graph is most strongly correlated with the cover of native and exotic species and with richness measures. Strongest among these are overall richness ($r^2 = 0.53$), exotic richness ($r^2 = 0.49$), exotic cover ($r^2 = 0.45$), native richness ($r^2 = 0.44$) and native cover ($r^2 = 0.44$; Table 5). Due to its dependence on native richness, FQI was also among those dependent variables most strongly correlated with the ordination results ($r^2 = 0.36$). The r^2 value for Mean C was 0.27. Among independent variables, topsoil Ca ($r^2 = 0.27$) and topsoil cation exchange capacity ($r^2 = 0.24$) have the strongest correlations to community composition. As was true for plots occurring on native soils, subsoil Zn ($r^2 = 0.22$) is among those independent variables with the strongest relationship to community composition (Table 5). Subsoil zinc has a negative relationship with FQI, and to a lesser extent Mean C.

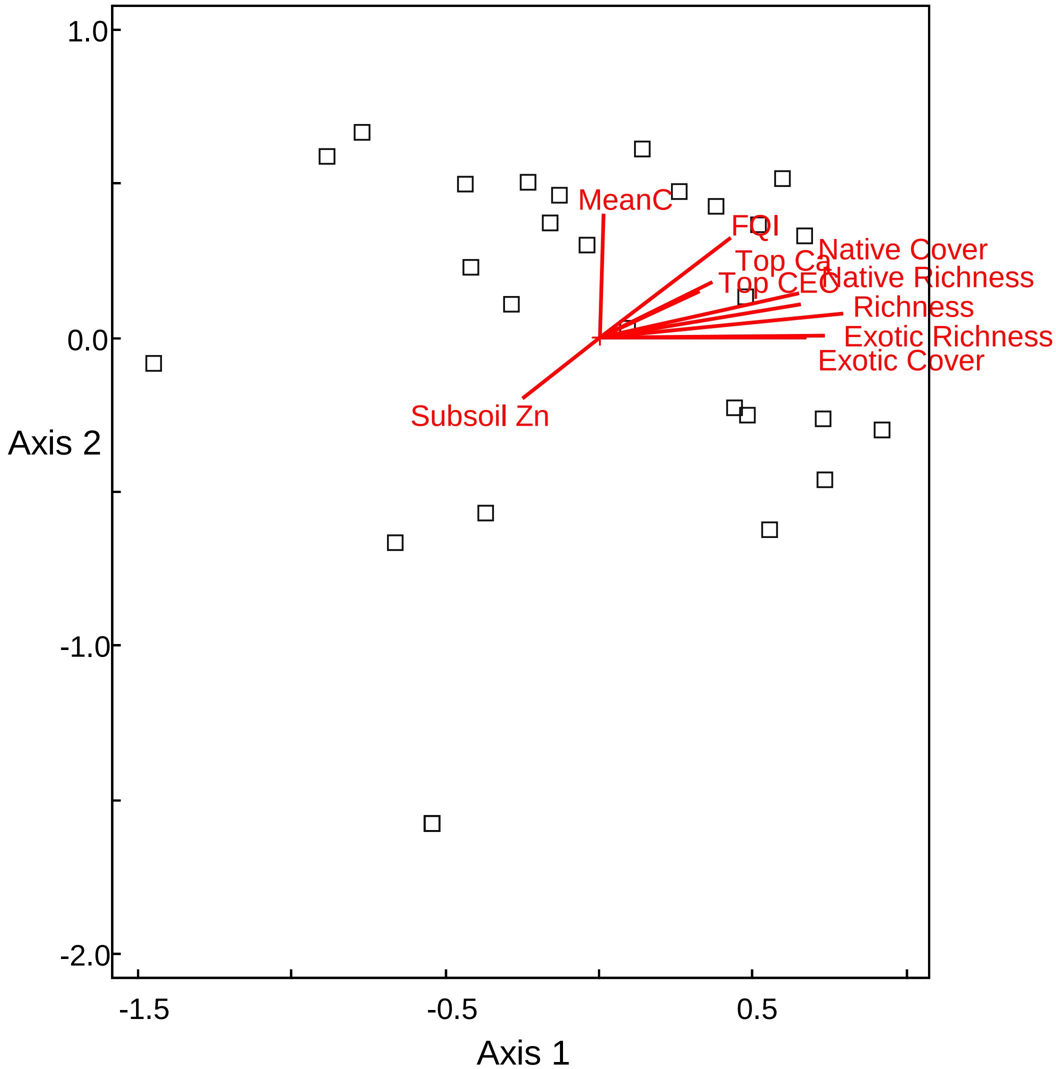


Figure 12. PC-ORD NMS output showing distribution of untreated mine waste plots and those variables most correlated to community composition (red lines; $r^2 > 0.20$).

Table 5. Multiple r^2 values for variables in relation to NMS ordination axes.
ND= no data

Variable	All Plots (Figure 10)	All Native Plots (Figure 11)	Untreated Waste Plots (Figure 12)
# of Axes in NMS Solution	3	2	3
Richness	0.73	0.03	0.53
Exotic Richness	0.48	0.47	0.49
Native Richness	0.73	0.02	0.44
Exotic:Native (richness)	0.44	0.51	0.22
Exotic Cover	0.29	0.20	0.45
Native Cover	0.79	0.27	0.44
Exotic:Native (cover)	0.32	0.18	0.19
Mean C	0.53	0.71	0.27
FQI	0.78	0.14	0.36
Topsoil Pb	0.13	0.40	0.09
Topsoil Cd	0.24	0.20	0.15
Topsoil Zn	0.30	0.37	0.08
Topsoil pH	0.09	0.20	0.02
Topsoil NA	0.19	0.21	ND
Topsoil OM%	0.48	0.02	0.20
Topsoil P	0.25	0.34	0.05
Topsoil Ca	0.32	0.26	0.27
Topsoil Mg	0.29	0.19	0.11
Topsoil K	0.54	0.18	0.14
Topsoil CEC	0.49	0.05	0.24
Subsoil Pb	0.20	0.46	0.12
Subsoil Zn	0.47	0.60	0.22
Subsoil pH	0.16	0.02	0.10
Subsoil NA	0.24	0.24	ND
Subsoil OM%	0.41	0.03	0.06
Subsoil P	0.13	0.32	0.07
Subsoil Ca	0.15	0.20	0.16
Subsoil Mg	0.23	0.21	0.06
Subsoil K	0.45	0.05	0.06
Subsoil CEC	0.38	0.08	0.14
Mean Pb	0.15	0.45	0.10
Mean Zn	0.41	0.53	0.16

Regression Tree Analysis

Least squares regression trees using all metal data (topsoil and subsoil Zn and Pb concentrations) in addition to all nutrient data as independent variables explained 61% (native soil) and 66% (mine waste) of the variation in Mean C (Table 6, Figures 13 and 14). The native soils model identified only metals (topsoil Zn, subsoil Pb and topsoil Pb) as the principal explanatory variables with roughly equal fit values for all three selected explanatory variables (Table 6). The mine waste model selected topsoil K (first and third) and topsoil pH (second) as the best explanatory variables for Mean C; fit was low (0.20) for the first explanatory variable (topsoil K) and highest (0.65) for the second explanatory variable (topsoil pH, Table 6). Using all metals and nutrient variables, regression trees for native soil sites and mine waste sites explained 64% and 71% of the variation in FQI, respectively (Table 6). The model selected topsoil Zn and then topsoil and subsoil CEC as the explanatory variables for FQI on native substrates. The model selected topsoil K, topsoil organic matter, and subsoil Zn as the explanatory variables for FQI on untreated mine waste sites (Table 6).

Table 6. Least squares regression tree splits, selected variables and cut values for Mean C and FQI in plots on native soil substrates and mine waste substrates.

Numbers of plots per node and mean values of response variables are shown in Figures 15-16.
PRE = proportional reduction in error. Final PRE value estimates variation in dependent variable explained by the overall model.

Split	Variable	Cut Value	PRE	Improvement	Fit
	Mean C on native soil substrates				
1	Topsoil Zn (mg/kg)	615.7	0.41	0.41	0.41
2	Subsoil Pb (mg/kg)	34.3	0.53	0.12	0.37
3	Topsoil Pb (mg/kg)	212.7	0.61	0.07	0.41
	Mean C on untreated mine waste substrates				
1	Topsoil K (lbs/ac)	38.0	0.20	0.20	0.20
2	Topsoil pHs	7.6	0.57	0.36	0.65
3	Topsoil K (lbs/ac)	136.0	0.66	0.09	0.39
	FQI on native soil substrates				
1	Topsoil Zn (mg/kg)	615.7	0.33	0.33	0.33
2	Topsoil CEC (meq/100g)	12.0	0.53	0.20	0.33
3	Subsoil CEC (meq/100g)	7.7	0.64	0.11	0.46
	FQI on untreated mine waste substrates				
1	Topsoil K (lbs/ac)	38.0	0.38	0.38	0.37
2	Topsoil OM (pct)	0.4	0.54	0.16	0.54
3	Subsoil Zn (mg/kg)	196.7	0.71	0.17	0.53

Both the Mean C and the FQI regression trees for native soil sites selected the same group of six plots at the first cut at the same Zn concentration (616 mg/kg); both Mean C and FQI values were higher in the plot clusters with topsoil Zn less than 615 mg/kg (Figure 13). Even after identifying these plots with high Zn concentration and low values for Mean C, the

Mean C model continued to select metals variables (subsoil and topsoil Pb at 34 mg/kg and 213 mg/kg, respectively) as the primary explanatory variables. The FQI model for plots on native substrates selected other soil variables (topsoil and subsoil CEC at 12 meq/100g and 8 meq/100g) as secondary and tertiary explanatory variables. This suggests that metals concentrations (especially Pb at very low levels) best explain differences in Mean C in native soil plots, and Zn concentration and other soil properties explain differences in FQI in native soil plots. Neither of the models for Mean C and FQI on untreated mine waste selected metals concentrations at the first cut, but the model for FQI identified subsoil Zn (at 197 mg/kg) as one of two secondary variables (Figure 14). In these plots, which have very low Mean C and FQI values, we cannot discount that metals concentrations may be sufficiently high to exclude all but the least conservative of species.

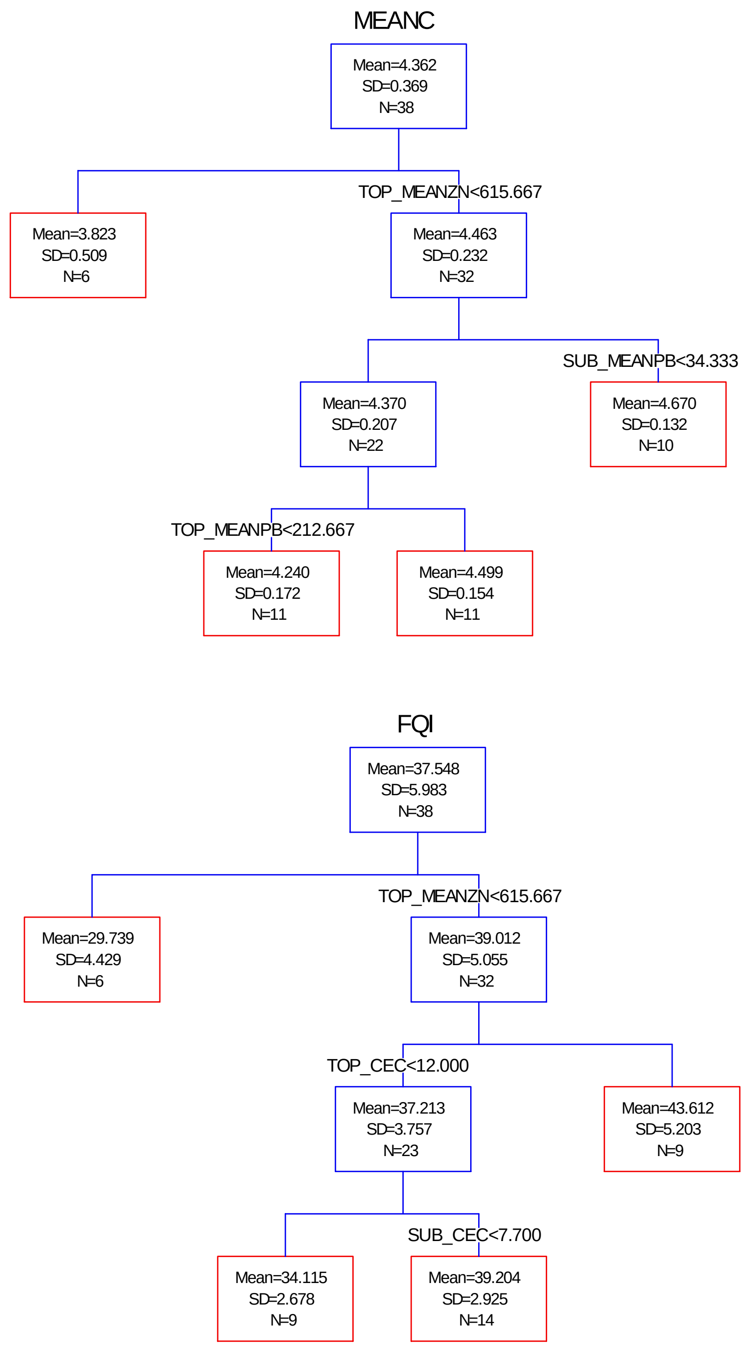


Figure 13. Least squares regression trees showing the top three variables that explain variation in Mean C and FQI for plots on native soil substrates*.

*Splits in the tree identify which variable at what value was selected to subdivide the group into clusters with similar response variable values. Boxes give the mean and standard deviation of the response variable and the number of plots in each cluster. Blue boxes are intermediate groups; red boxes are final clusters that cannot be further subdivided.

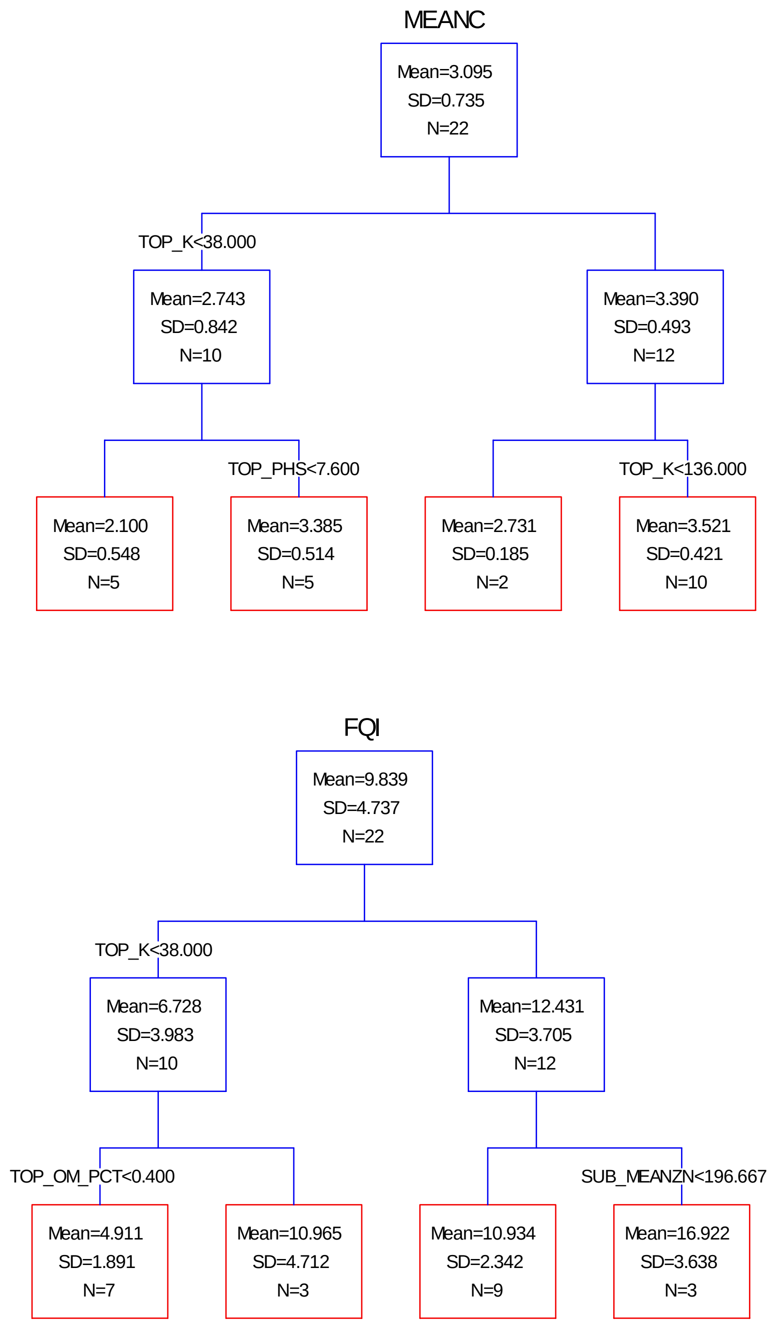


Figure 14. Least squares regression trees showing the top three variables that explain variation in Mean C and FQI for plots on untreated mine waste substrates*.

* Splits in the tree identify which variable at what value was selected to subdivide the group into clusters with similar response variable values. Boxes give the mean and standard deviation of the response variable and the number of plots in each cluster. Blue boxes are intermediate groups; red boxes are final clusters that cannot be further subdivided.

Means Testing

Site Types

All mine waste site types had significantly lower Mean C and FQI than all native soil site types (Table 7, Figure 15). Mean C on untreated mine waste (3.10) was 33 percent lower than on reference summits (4.63) and 30 percent lower than on reference bottoms (Table 7). Mean C on remediated mine waste (3.10) was 46 percent lower than on reference summits and 44 percent lower than on reference bottoms (Table 7). Mean C on revegetated mine waste was 26 percent lower than on reference summits and 23 percent lower than on reference bottoms (Table 7). On untreated mine waste, FQI (9.42) was 73 percent lower than on reference summits (34.96) and 78 percent lower than on reference bottoms (43.76; Table 7). On remediated mine waste, FQI (10.04) was 71 percent lower than on reference summits and 77 percent lower than on reference bottoms (Table 7). On revegetated mine waste, FQI (16.30) was 53 percent lower than on reference summits and 63 percent lower than on reference bottoms (Table 7).

Among plots located on native soils, differences in Mean C were not statistically significant. Mean FQI was significantly higher in reference bottoms (43.76) than in both reference summits (34.96) and contaminated native soil sites (35.94), but not significantly higher than in smelter contaminated sites (40.38; Table 7, Figure 15). The higher FQI in reference bottoms relative to reference summits is expected due to the higher floristic diversity of bottom versus summit landforms in the region. These landform types were specifically selected in order to represent the range of native plant diversity in the area. In addition, several contaminated soil plots and smelter contaminated soil plots fell by coincidence on landforms that were neither summit or bottom, but on landforms with variable depth to bedrock, a floristically diverse landform type in the region (Nigh and others 2000). Therefore, examining floristic quality results for the *a priori* groups does not specifically address effects of metals contamination, especially given the overlap of metal contamination range among site types.

Within mine waste sites, differences in Mean C were not statistically significant. Mean FQI was significantly higher on revegetated mine waste sites (16.30) than on either untreated mine waste (9.42) or remediated mine waste (10.04; Table 7, Figure 15).

Table 7. ANOVA and Tukey Multiple Comparison test results for Mean C and FQI among *a priori* site types, and comparison of all *a priori* type means to reference type means .

ANOVA: n = 85; df = 6; error df = 78. Tukey: Mean values in the same column with different letters are significantly different ($p < 0.01$)

	Mean C					FQI				
ANOVA										
Source	Sum-of-Squares	Mean-Square	F-ratio	P	Multiple R^2	Sum-of-Squares	Mean-Square	F-ratio	P	Multiple R^2
Site Type	37.76	6.29	19.79	<0.01	0.60	15543.67	2590.61	109.51	< 0.01	0.89
Error	24.80	0.32				1845.29	23.66			

Tukey Multiple Comparison Test Results and Comparison to Reference Types

	Mean C	% relative to Ref. Summits	% relative to Ref. Bottoms	FQI	% relative to Ref. Summits	% relative to Ref. Bottoms
Reference Summit	4.63a	-	105	34.96a	-	80
Reference Bottom	4.41a	95	-	43.76b	125	-
Contaminated Native Soil	4.26a	92	97	35.94a	103	82
Smelter Contaminated	4.50a	97	102	40.38ab	115	92
Untreated Mine Waste	3.10b	67	70	9.42c	27	22
Remediated Mine Waste	2.48b	54	56	10.04c	29	23
Revegetated Mine Waste	3.40b	74	77	16.30d	47	37

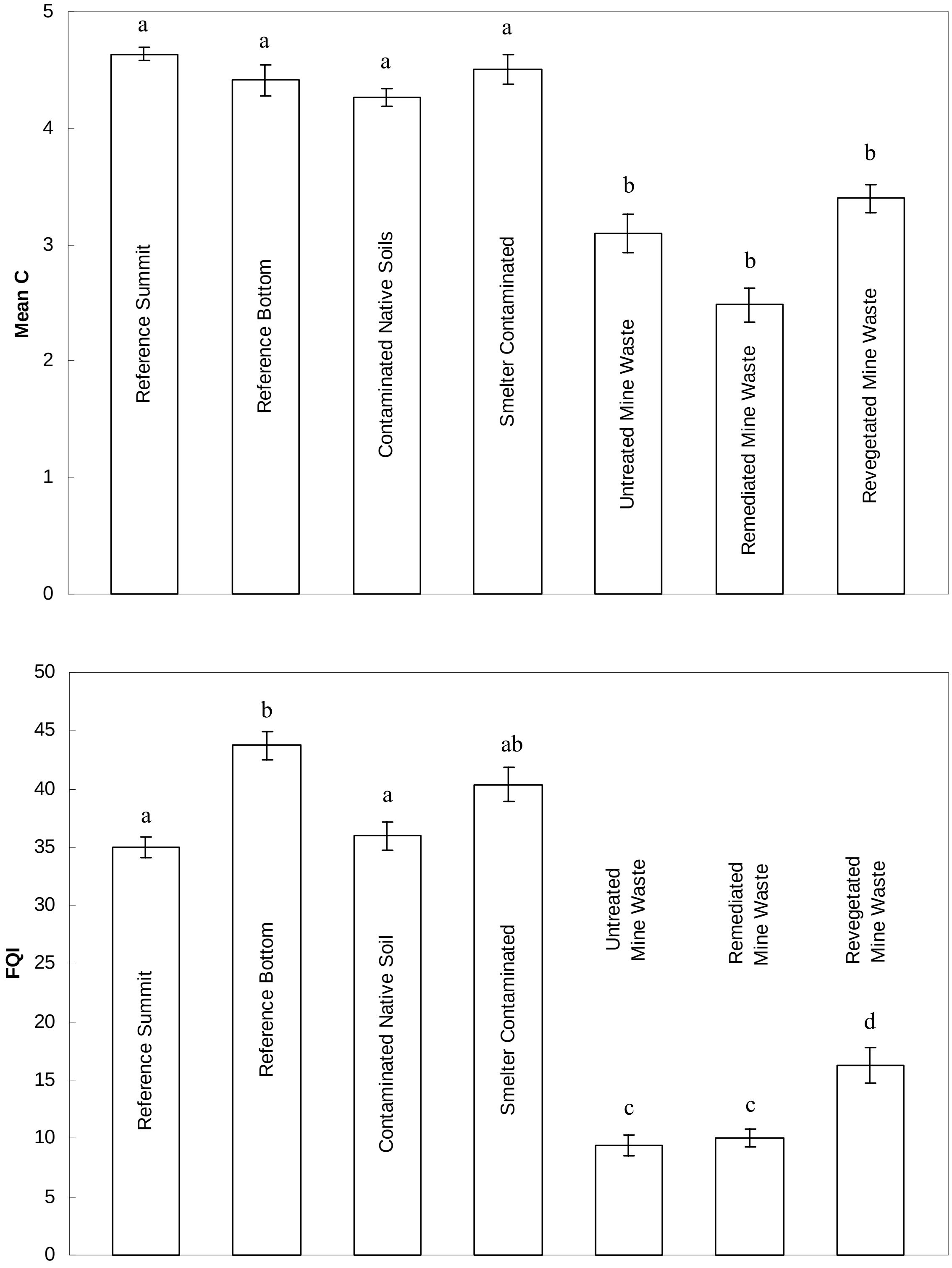
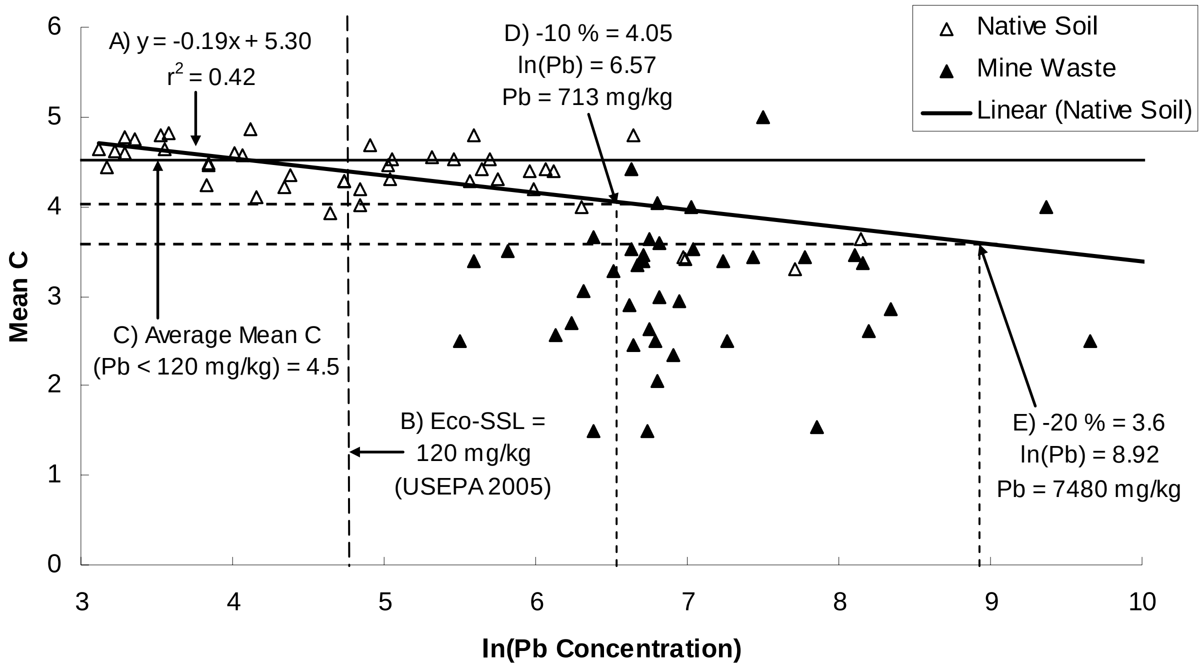


Figure 15. Mean* and standard error for Mean C and FQI among *a priori* site types.

*Mean values with different letters are significantly different ($p < 0.05$)

Eco-SSLs

Nineteen of 44 native soil plots had topsoil Pb concentrations below the Eco-SSL of 120 mg/kg, while 29 plots had subsoil Pb concentrations below the Eco-SSL (USEPA 2005; Table 8). Eighteen plots had topsoil Zn concentration below an expert-identified threshold of 70 mg/kg (Kaputska 2007), while 21 plots had subsoil Zn concentrations below that threshold (Table 9). Ten plots had topsoil Zn concentrations above the Eco-SSL of 160 mg/kg (USEPA 2007), while subsoil Zn concentration exceeded the Eco-SSL in six native soil plots (Table 9). All plots on untreated mine waste had Pb concentrations in excess of the Pb Eco-SSL, and all but two plots had Zn concentrations above the Eco-SSL. Because we could find no published, biologically relevant threshold above Eco-SSLs for Pb and Zn by which to subdivide the data for untreated mine waste sites, we did not perform means tests on untreated mine waste. Figure 16 displays Mean C against topsoil and subsoil Pb and Zn concentrations in relation to phytotoxicity thresholds. Figure 17 displays FQI against topsoil and subsoil Pb and Zn concentrations in relation to phytoxicity thresholds.



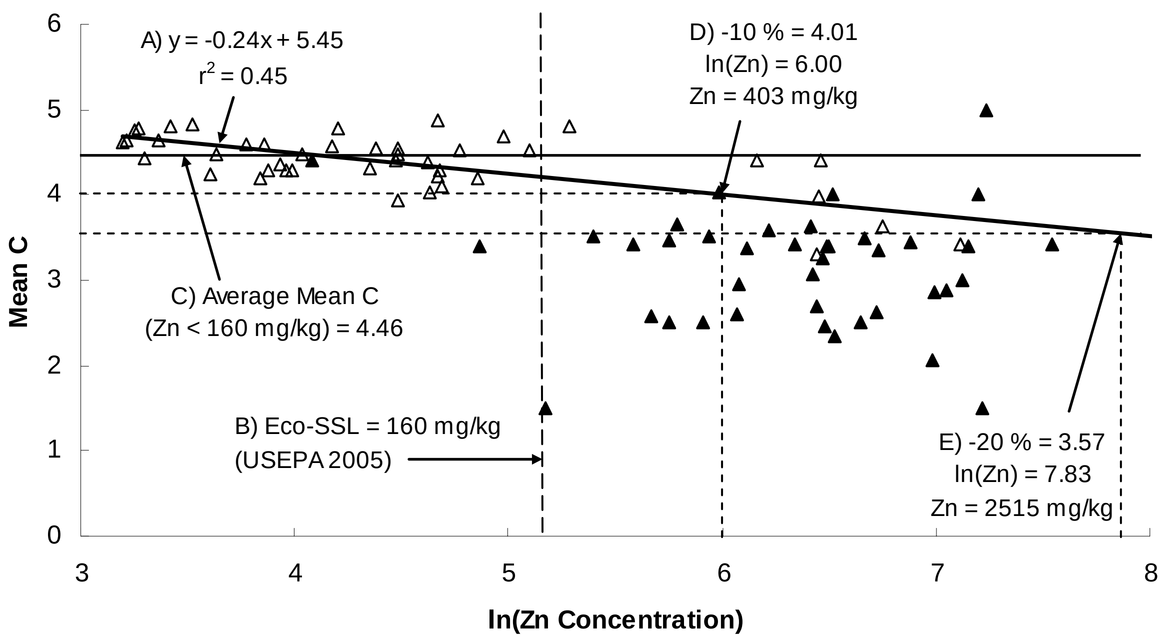
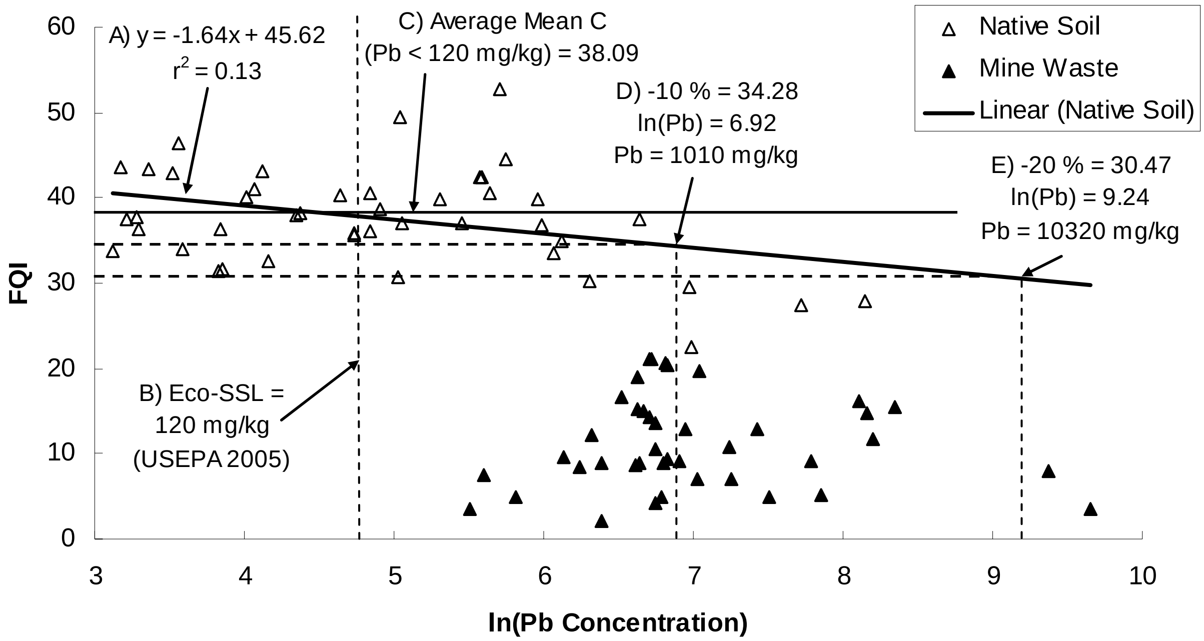


Figure 16. Scatterplot of Mean C against natural log (ln)-transformed mean metals concentrations for all plots with regression equation based on native soils (A), reference values for phytotoxicity thresholds for Pb and Zn (B), the average Mean C for all native soil plots below Eco-SSL (C), and concentrations with expected reductions of 10 percent (D) and 20 percent (E) from that value.



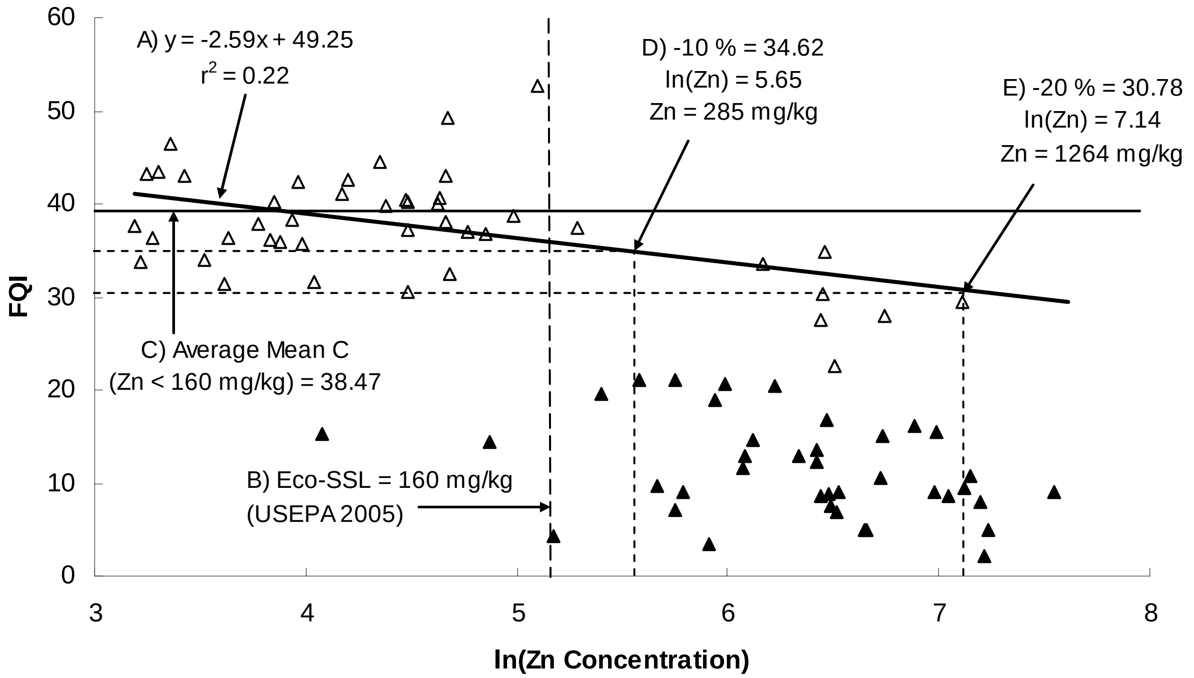


Figure 17. Scatterplot of FQI against natural log (ln)-transformed mean metals concentrations for all plots with regression equation based on native soils (A), reference values for phytotoxicity thresholds for Pb and Zn (B), the average Mean C for all native soil plots below Eco-SSL (C), and concentrations with expected reductions of 10 percent (D) and 20 percent (E) from that value.

Plots on native soils with Pb concentrations below Eco-SSLs had significantly higher values than those below Eco-SSLs for Mean C but not for FQI ($p < 0.05$; Table 8). Analysis of Variance comparing Mean C and FQI among three classes of soil Zn concentration showed significant differences for topsoil, subsoil and averaged Zn concentration ($p < 0.05$; Table 9). Regardless of soil layer, lower Mean C was associated with higher Zn concentration ranges, and FQI showed a slight increase between the lowest Zn concentration (< 70 mg/kg) and the middle class ($70 \leq Zn < 160$), then a large drop in the highest Zn concentration class (Table 9).

Table 8. Results of t-tests assuming unequal variance comparing average Mean C and mean FQI for plots on native soils with metals concentrations above and below USEPA Eco-SSL for Pb (120 mg/kg).

	Mean C				FQI			
Pair	N	Mean	SD	p	N	Mean	SD	p
Top Pb < 120	19	4.52	0.26	0.01	19	38.34	4.39	0.42
Top Pb ≥ 120	25	4.24	0.41		25	36.97	6.79	
Sub Pb < 120	29	4.46	0.25	0.05	29	37.76	3.97	0.80
Sub Pb ≥ 120	15	4.18	0.50		15	37.16	8.57	
Mean Pb < 120	21	4.50	0.25	0.02	21	38.09	4.24	0.56
Mean Pb ≥ 120	23	4.24	0.43		23	37.07	7.08	

Table 9. ANOVA and Tukey Multiple Comparison test results comparing Mean C and FQI among three classes of topsoil, subsoil and averaged soil Zn concentration (mg/kg) in plots on native substrate.

ANOVA: n= 44; df = 2; error df = 41. Tukey: Mean values in the same row with different letters are significantly different ($p < 0.05$)

	Mean C					FQI				
	ANOVA									
Source	Sum-of-Squares	Mean-Square	F-ratio	P	Multiple R^2	Sum-of-Squares	Mean-Square	F-ratio	P	Multiple R^2
Topsoil Zn	1.51	0.75	6.79	<0.01	0.25	233.44	116.72	3.86	0.03	0.16
Error	4.56	0.111				1239.53	30.23			
Subsoil Zn	2.35	1.18	12.98	<0.01	0.39	430.35	215.17	8.46	<0.01	0.29
Error	3.72	0.09				1042.62	25.43			
Mean Zn	1.83	0.92	8.85	<0.01	0.30	247.34	123.67	4.14	0.02	0.17
Error	4.24	0.10				1225.63	29.89			

	Tukey Multiple Comparison Test					
	Zn < 70 (n)	70 ≤ Zn < 160 (n)	Zn ≥ 160 (n)	Zn < 70	70 ≤ Zn < 160	Zn ≥ 160
Topsoil Zn	4.54a (18)	4.35ab (16)	4.06b (10)	37.97ab	39.61a	33.52b
Subsoil Zn	4.54a (21)	4.34a (17)	3.83b (6)	38.37a	39.31a	29.76b
Mean Zn	4.53a (20)	4.37a (15)	3.99b (9)	38.35a	39.26a	32.95b

Univariate Regression

For plots on native soils, univariate least squares linear regression indicated significant negative relationships between both Mean C and FQI and concentrations of Pb and Zn in topsoil, subsoil, and average soil concentrations ($p < 0.05$; Table 10; Figures 18 and 19). The negative relationships were stronger (greater r^2 values) for Mean C than for FQI. Within each native soil layer (topsoil, subsoil or mean), Zn concentration explained more of the variation in both Mean C and FQI than did Pb concentration. For untreated mine waste, a significant negative relationship was found between FQI and subsoil Zn concentration (Table 10; Figures 20 and 21).

Using regression equations for native soil plots (Table 10), we calculated concentrations of Pb and Zn at which one could expect to see reductions of 10 and 20 percent in Mean C and FQI compared to the mean value of these measures on sites with concentrations below Eco-SSLs (120 mg/kg for Pb and 160 mg/kg for Zn). For Mean C, a ten percent reduction can be expected at concentrations of 713 mg/kg for Pb and 403 mg/kg for Zn. A twenty percent reduction can be expected at concentrations of 7,480 mg/kg for Pb and 2,515 mg/kg for Zn (Figures 16 and 17). For FQI, a ten percent reduction can be expected at concentrations of 1,010 mg/kg for Pb and 285 mg/kg for Zn. A twenty percent reduction can be expected at concentrations of 10,320 mg/kg for Pb and 1,264 mg/kg for Zn (Figures 16 and 17). Similar calculations can be made for either the topsoil or subsoil using the appropriate regression equations in Table 10.

Five contaminated native soil plots exceeded the Pb concentration at which one could expect to see a ten percent reduction in Mean C; four of the same plots exceeded the Pb concentration at which you would expect to see a ten percent reduction in FQI (Figure 16). Seven contaminated native soil plots had Zn concentrations that exceeded the concentrations at which one could expect to see a ten percent reduction in both Mean C and FQI (Figure 17).

Approximately 50 percent of plots occurring on mine waste exceeded the concentrations of Pb and Zn at which one would expect a to see a ten percent reduction in Mean C (Figure 16). Approximately 50 percent of all mine waste plots exceeded the concentration for Pb at which one would expect to see a 10 percent reduction in FQI, while about 90 percent of plots on mine waste exceeded the concentration of Zn at which one would expect a to see a ten percent reduction in FQI (Figure 17). Two untreated mine waste plots exceeded the concentrations for Pb at which one would expect to see a twenty percent reduction in both Mean C and FQI. Six untreated mine waste plots exceeded the Zn concentration at which one would expect a 20 percent reduction in FQI.

Table 10. Results of least squares linear regression of Mean C and FQI against ln-transformed Pb and Zn concentrations from topsoil, subsoil, and mean soil.

Native Soil Substrates						
	Mean C			FQI		
Independent variable	coefficient	intercept	P	coefficient	intercept	p
Topsoil Pb	-0.165	5.226	< 0.01	-1.423	44.985	0.04
Subsoil Pb	-0.217	5.308	< 0.01	-1.780	45.305	0.01
Mean Pb	-0.191	5.303	< 0.01	-1.640	45.624	0.02
Topsoil Zn	-0.206	5.320	< 0.01	-2.201	47.788	< 0.01
Subsoil Zn	-0.292	5.618	< 0.01	-2.980	50.339	< 0.01
Mean Zn	-.0240	5.540	< 0.01	-2.586	49.246	0.00

Untreated Mine Waste (excludes remediated and revegetated site types)						
	Mean C			FQI		
Independent variable	coefficient	intercept	P	coefficient	intercept	p
Topsoil Pb	0.072	5.580	0.63	0.498	5.823	0.56
Subsoil Pb	0.005	3.065	0.98	0.648	4.818	0.54
Mean Pb	0.047	2.757	0.77	0.534	5.587	0.57
Topsoil Zn	0.057	2.822	0.78	-1.155	17.204	0.33
Subsoil Zn	0.009	3.104	0.96	-2.137	22.827	0.05
Mean Zn	0.049	2.879	0.81	-1.654	20.272	0.16

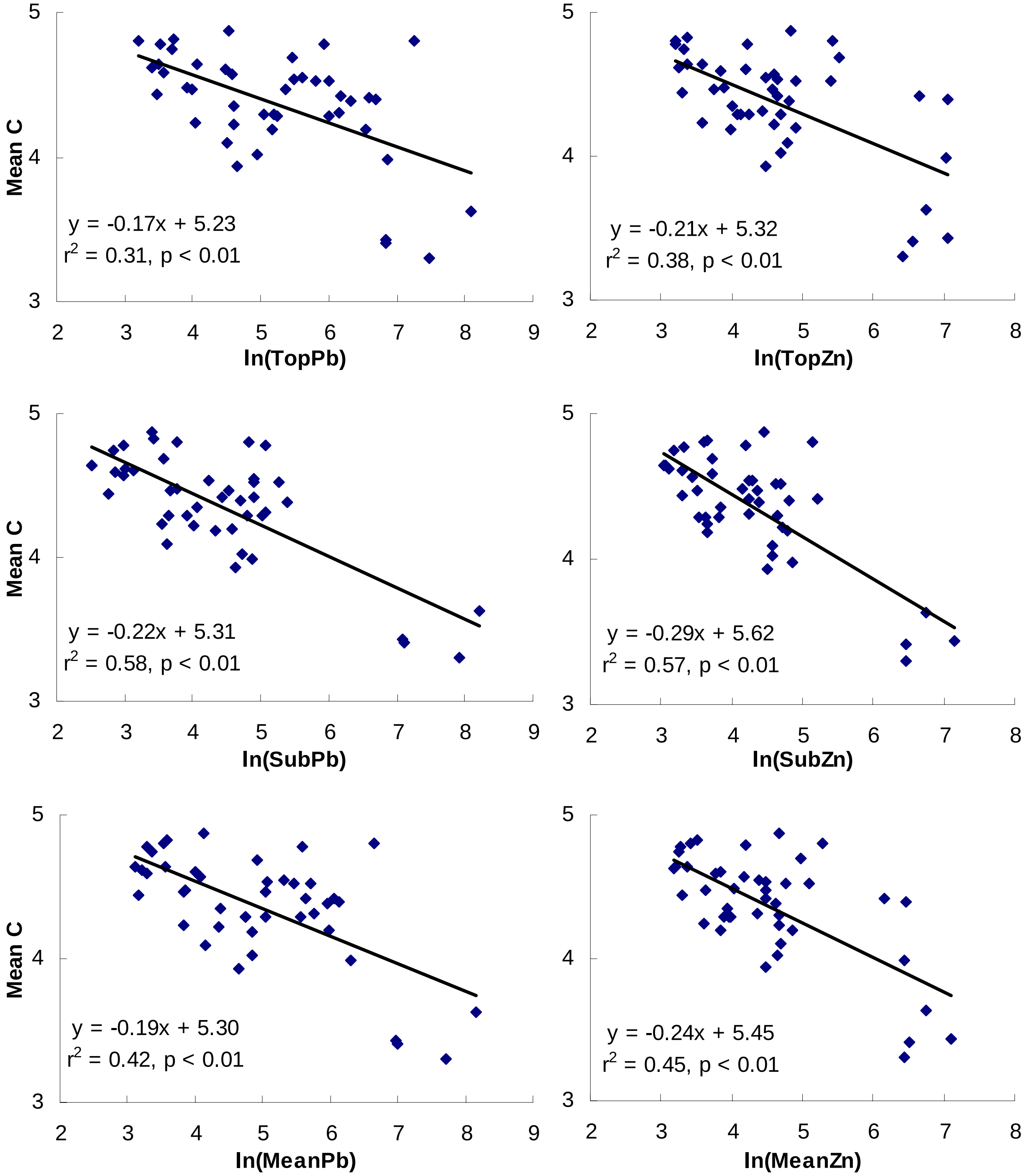


Figure 18. Least squares linear regression of Mean C against ln-transformed metals concentrations for plots on native soils (n = 44).

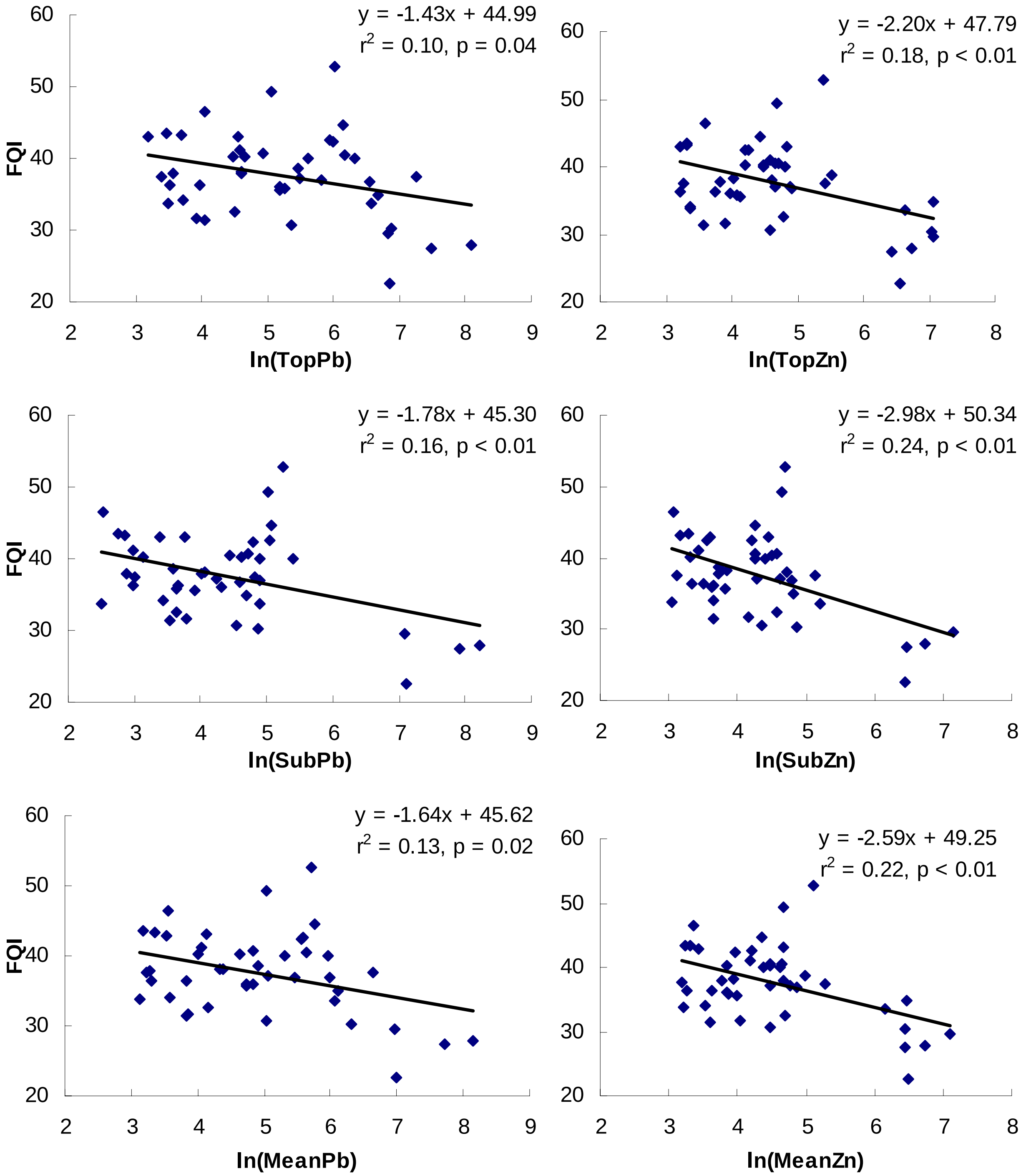


Figure 19. Least squares linear regression of FQI against ln-transformed metals concentrations for plots on native soils (n = 44).

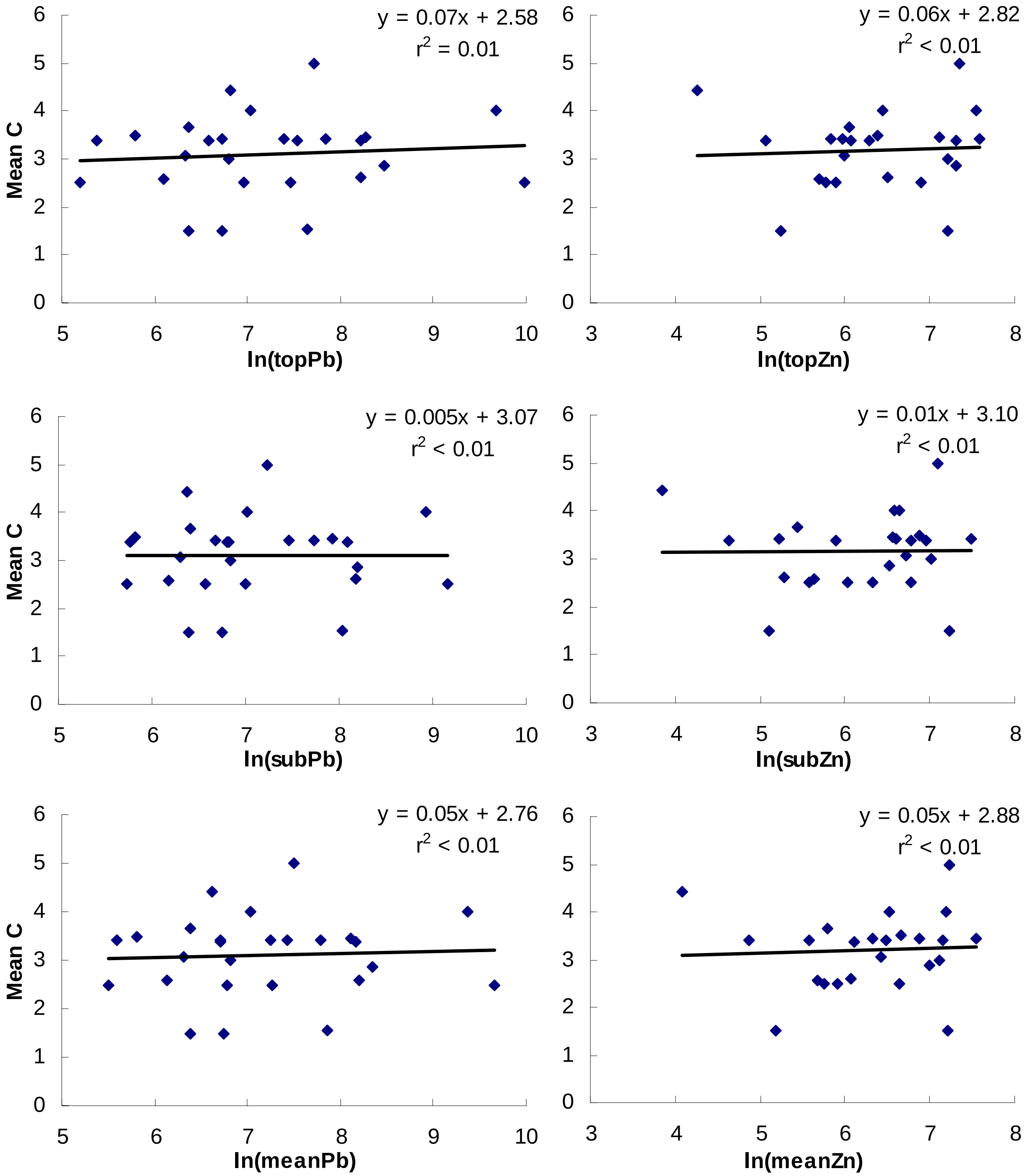


Figure 20. Least squares linear regression of Mean C against ln-transformed metals concentrations for plots on untreated mine waste ($n = 26$; $p > 0.6$).

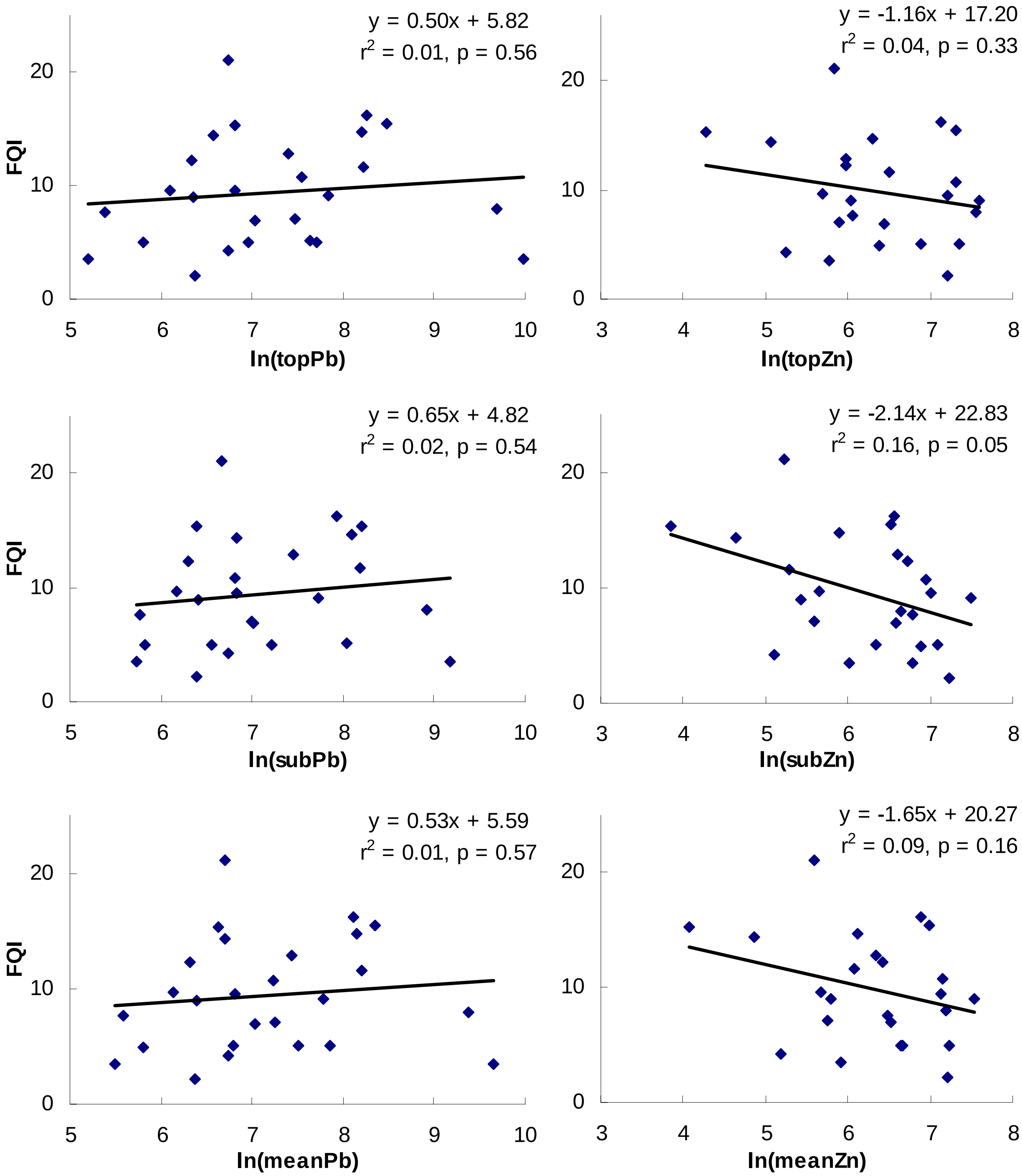


Figure 21. Least squares linear regression of FQI against ln-transformed metals concentrations for plots on untreated mine waste (n = 26).

Discussion

Data from this study demonstrate that increased soil Pb and Zn concentrations are among the most important variables associated with decreased floristic quality. Non-Metric Multidimensional Scaling and Regression Tree Analysis both identify higher Pb and Zn concentrations as important variables associated with decreased Mean C and FQI. Means testing among *a priori* site types shows significantly lower Mean C and FQI values on mine waste compared to native soil. Means testing using Eco-SSLs indicate significantly lower Mean C and FQI in sites with Pb and Zn concentrations above Eco-SSLs compared with those with concentrations below Eco-SSLs. Finally, univariate least-squares linear regression shows a negative relationship between Mean C (and to a lesser extent FQI) and metals concentrations. The strongest relationships between Pb and Zn concentrations and diminished Mean C and FQI are shown on native soils, for which all plots exhibited minimal human disturbance, indicating that the results are due to chemical effects of contamination from mine waste, rather than physical effects. Relationships between Pb and Zn concentrations and floristic quality were not as strong on mine waste plots, where Mean C and especially FQI were very low; we cannot rule out the possibility that metals concentrations may be sufficiently high to exclude all but the least conservative of species. However, even at highly disturbed sites on mine waste, higher Zn concentrations are associated with decreased floristic quality.

Analysis using NMS analyses indicated that plant community species composition on mine waste substrate differed significantly from species composition in native soil plots. Mine waste sites were dominated by non-native species and by species tolerant of disturbance as determined by coefficients of conservatism. Analysis using NMS also indicated 1) that metals concentrations are critical environmental variables explaining species composition and abundance, and 2) that as metals concentrations increase, Mean C values decrease.

Four plots in NMS analysis cluster separately from the other native soil plots at the top of Figure 11. These plots are the only ones located on large river floodplains and they include a suite of flood-adapted species encountered nowhere else in this study. This may explain why they represent a distinct group in the NMS ordination output (Figure 11). It may also partly explain why these sites had a lower Mean C than all other native soil plots (Table 4); lower mean C values have been associated with sites prone to flooding disturbance (McIndoe and others 2008). However, these plots are among the plots with the highest Pb and Zn concentrations throughout the soil profile and are the only plots located both downstream and downslope from potential sources of mine waste. The convergence of the above factors suggests that more research is needed to characterize the impact of elevated metals concentrations on floristic quality in large river floodplain systems. The negative relationship between Zn concentration and floristic quality shown in the NMS output was supported by our other lines of analysis.

Lower floristic quality was associated with higher Pb and/or Zn concentrations on both native soil and mine waste through regression analyses. In regression tree analysis, differences in Mean C were best explained by soil Zn and Pb concentrations in native soil plots and by other soil factors (K and pH) in mine waste plots. Regression tree models selected topsoil Zn concentration and cation exchange capacity to explain differences in FQI on native soil and K, organic matter and subsoil Zn to explain FQI differences on mine waste sites. It is not surprising that organic matter content, pH and cation exchange capacity were selected by the models to explain differences in floristic quality, as these affect the bioavailability and uptake of heavy metals by plants (Brown and others 1995, 2005). In mine waste plots, which are physically and biologically extreme sites, changes in soil chemistry, especially those related to organic matter content, may have a more visible effect on plant community than further increases in already high metal concentration. Thus, changes in organic matter, cation exchange capacity and pH on mine waste may show greater impact on plant communities either by providing limited nutrients in these extreme environments or by ameliorating the bioavailability of metals. Nevertheless, metals concentrations are identified as critical factors explaining floristic quality, even in these extreme environments.

In native soil sites, least squares linear regression indicated significant negative relationships between Mean C and both Pb and Zn concentrations, with Zn concentration explaining more of the variation in both measures, regardless of soil layer. Seven plots on contaminated native soils had either Pb or Zn concentrations in excess of values at which one could expect a 10 percent reduction in floristic quality. By extrapolating patterns seen on native soils, we observe that more than 90 percent of plots occurring on mine waste had either Pb or Zn concentrations in excess of values at which one could expect to see a ten percent reduction in floristic quality measures. This suggests that one would expect at least a 10 percent reduction in floristic quality on these mine waste plots that is associated with increased metals concentrations, regardless of the physical property differences in mine waste and soil substrates.

For untreated mine waste sites, only subsoil Zn was identified in both regression tree analysis and univariate regression as important to differences in floristic quality. The inability to detect floristic quality changes on mine waste in response to other metals variables could be an artifact of the inherently low quality of the vegetation on these sites. On the one hand, lack of observed response to increasing metals concentrations may reflect biological reality on mine waste sites. Once Mean C has been degraded to a low level, it becomes increasingly difficult to affect change in that value (Swink and Wilhelm 1994). Furthermore, mine waste has a greater proportion of species with low C values, which are shown in this study—by the negative relationship between Mean C and metals concentrations on native soils—to be less adversely affected by increasing metals concentrations than are conservative species (lower Mean C represents a relative increase in the diversity of less conservative species). In other words, mine waste sites are dominated by species less likely to respond to changes in metals concentrations.

On the other hand, a lack of observed response on mine waste plots to increasing metals concentrations may reflect the limitations of what can be done analytically with the given data set. Low species richness associated with mine waste plots allows one or two species to have a profound impact on Mean C values, increasing among-plot variation. For example, one untreated mine waste plot had a Mean C of 5 because it contained only one seedling of one species with a C value of 5. For FQI, the effect of one species with an unusually high C value is less profound (because the square root function used to compute FQI reduces the impact of the addition of one or two species). This fact is demonstrated by the proportionally smaller variance in FQI on untreated mine waste compared to Mean C. All untreated minewaste sites except one had FQI values less than 20, which reflects no significance as a natural area (Swink and Wilhelm 1994). Nevertheless, our data show that increasing Zn concentrations has a negative impact on the already low floristic quality on mine waste.

Means testing demonstrated significantly higher Mean C and FQI on all native soil site types compared to all site types on mine waste. On mine waste, Mean C ranged from 56 to 77 percent of values found on reference bottoms, which had the lower mean C of our two reference types. On mine waste, FQI ranged from 27 to 47 percent of values found on reference summits, the reference type with the lower FQI value. Our data show no significant difference in Mean C between untreated, remediated and revegetated mine waste plots. However, differences in treatment type and time since treatment create large amounts of variability within the site types. More study is needed to make conclusions about differences in floristic quality among revegetation and remediation efforts.

Lower floristic quality was also associated with higher Zn and Pb concentration ranges via means testing. Mean C values were significantly higher in native soil sites with Pb concentrations below the Eco-SSL of 120 mg/kg compared to those above this level. Generally, Mean C was 6 percent lower in sites with Pb concentrations above the Eco-SSL. Mean C in plots with soil Zn concentrations above the Eco-SSL of 160 mg/kg was 11 to 16 percent lower than Mean C in plots with soil Zn concentrations below 70 mg/kg. Mean C in plots with Zn concentrations above 160 mg/kg was 8 percent lower for subsoil and 12 percent lower for mean soil than Mean C in plots with subsoil and averaged soil Zn concentrations between 70 and 160 mg/kg.

Mean C values for plots above and below 120 mg/kg Pb and for all of the Zn concentration classes are all considered to be reflective of natural conditions (i.e., Mean C above 3.5). This is not surprising, because our selection criteria for all native soil types, including contaminated soil types and smelter types required that sites be undisturbed by logging, grazing or other activities. However, between-group differences for Mean C as small as 0.25 were statistically significant when comparing plots with soil Pb concentrations above and below 120 mg/kg and as small as 0.38 when comparing plots with soil Zn concentrations above and below 160 mg/kg. By comparison, others have found significant Mean C differences of 0.9 and 1.5 when comparing relatively undisturbed natural wetlands to 8 year-old and 3 year-old restored wetlands (Mushet and others 2002); and significant differences of 0.4 in remnant prairies with differing ownership classes and management practices (Higgins and others 2001). Our study found statistical significance for smaller differences in Mean C, indicating significant effects to floristic quality in otherwise undisturbed sites associated with relatively low metal concentration ranges.

Floristic Quality Index values were significantly lower in native soil plots with Zn concentrations above 160 mg/kg compared to plots with 70-160 mg/kg. The FQI values exceeded 37 in plots with Zn < 70 mg/kg and < 160 mg/kg regardless of soil layer, and FQI was less than 34 in plots with Zn > 160 mg/kg for all soil layers. Typically, FQI values above 35 are suggestive of natural value (Swink and Wilhelm 1994); this indicates that the otherwise undisturbed sites with Zn concentrations above 160 mg/kg fall below what is typically considered to have natural value. Differences in FQI among the Zn concentration classes ranged from 6.09 to 9.55 depending on soil layer; differences in FQI as small as 0.2 can indicate degraded natural community conditions (Swink and Wilhelm 1994, Rothrock and Homoya 2005).

We were unable to assess the association between Cd concentration and floristic quality metrics due to the inability of our metal detection instrument to detect Cd concentrations below 50 mg/kg, which is above the Eco-SSL of 32 mg/kg. However, Cd has been shown to have frequency distributions similar to Zn concentrations in U.S. soils (Holmgren and others 1993). The estimated crustal ratio of Zn to Cd is 270 (Tourtelot and others 1964, as cited in Holmgren and others 1993); in tested organic Missouri soils, the geometric mean of the Zn to Cd ratio is 200-249 (Holmgren and others 1993). In plots with higher Zn concentrations, it is probable that there are higher Cd concentrations as well. Thus, we cannot rule out that plant community effects related to Zn concentrations might also be due to Cd concentrations.

More than Pb, Zn soil concentrations were repeatedly identified as important explanatory variables for decreasing floristic quality. Our data support earlier field and laboratory studies that showed a negative effect of increasing Zn concentration on native plants. Pierzynski and Fick (2007) demonstrated decreasing richness with increasing total and bioavailable Zn concentration. Because FQI is proportional to richness, and given the negative relationship we documented between FQI and Zn concentrations, our data support this conclusion. The data also showed an increasing abundance of non-native species with increasing Zn concentration (Pierzynski and Fick 2007). While floristic quality assessment scores do not directly address non-native species, the impact of non-native species is frequently reflected in lower FQI values; increasing dominance by non-natives diminishes the likelihood that native species can become established, resulting in lower native richness. The lower FQI scores associated with greater Zn concentrations in our study may reflect a similar increasing abundance of non-native species and subsequent decrease in native species.

Our findings of lower Mean C and FQI on sites with increased Pb and Zn concentration on native soils support earlier research documenting the impact of elevated metals concentrations on community succession. Kaputska (2007) concluded that locations in the Big River Mines Tailings Superfund Site have concentrations of lead and zinc that are affecting plant community succession on contaminated native soils in the region. Furthermore, our finding of extremely low Mean C and FQI values on mine waste substrates supports Kaputska's (2007) claim that rehabilitation efforts are compromised on sites with elevated concentrations of Pb, Cd and Zn. Once a site has degraded to register a Mean C value below 3.0, there is little evidence to show that restoration efforts can improve Mean C more than a few tenths of a point without substantial effort to reintroduce conservative species (Swink and Wilhelm 1994). Furthermore, previous rehabilitation efforts that have created near-complete dominance by perennial, non-native species (as at remediated sites sampled for this study) may in fact be inhibiting vegetation succession toward communities with higher Mean C and FQI values. This may explain why remediated mine waste sites have only slightly improved FQI values compared to untreated mine waste. By contrast, revegetated sites where perennial native flora were planted (St. Joe SP and Leadwood) had FQI values 73 percent higher than untreated mine waste. However, it is also possible that some of the difference in floristic quality is due to the amount of time since treatment (Kimmerer 1984). The challenge of restoring areas to high floristic quality is due to the inability to assemble all of the biological and environmental factors that are required to recruit and sustain a suite of conservative species within a habitat type (Swink and Wilhelm 1994).

To date, little work has been done on effects of heavy metals on plant community composition and quality. Our study found inverse relationships between two floristic quality measures, Mean C and FQI with increasing concentration of Pb (for Mean C) and Zn (for both metrics) on mine waste and on native soil substrates in two mining districts in southeast Missouri. Zinc concentrations were identified repeatedly by various statistical approaches as related to floristic quality measures. These relationships were more pronounced on otherwise undisturbed native soil plots, indicating that elevated metals concentrations affect floristic quality where no other human disturbance is evident. In sites where nutrients or other soil characteristics best explained differences in floristic quality, as was suggested for untreated mine waste plots by both NMS analysis and regression tree analysis, subsoil Zn was still selected as a strong explanatory variable, even though all but two plots had subsoil Zn concentrations in excess of EcoSSLs. Our data indicate a negative impact above these Eco-SSLs on both native soils and mine waste substrates. Thus, we can reasonably expect that, even where nutrients are limiting factors for vegetation development on mine waste, elevated concentrations of metals (especially Zn) also affect floristic quality.

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Appendix I. Mean topsoil and subsoil Pb, Cd and Zn for all plots.

<LOD = below limit of detection; ND = No data

Plot name	Site type	Mean Pb (mg/kg)		Mean Cd (mg/kg)		Mean Zn (mg/kg)	
		Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
Desloge01	Remediated mine waste	1264.6	805.9	<LOD	<LOD	631	243.2
Desloge02	Contaminated native soil	931	1202.5	<LOD	<LOD	1171.9	1276.1
Desloge03	Remediated mine waste	843.4	685.8	<LOD	<LOD	540.7	762.3
Desloge04	Remediated mine waste	1019.7	770.3	<LOD	<LOD	1328.8	827.2
Desloge05	Contaminated native soil	100.7	58.3	<LOD	<LOD	55.4	46.8
Desloge06	Contaminated native soil	407.6	192.3	<LOD	<LOD	219.3	108.9
Desloge07	Remediated mine waste	951.2	1052.9	<LOD	<LOD	621.9	748
Desloge09	Remediated mine waste	887.9	823.7	<LOD	<LOD	883.2	784.2
Desloge10	Contaminated native soil	940.4	1219.8	<LOD	<LOD	698.5	634.6
Elvins01	Contaminated native soil	802.3	110	<LOD	<LOD	1155.7	123.7
Elvins02	Contaminated native soil	963.3	130.8	<LOD	<LOD	1135.7	129.6
Elvins03	Contaminated native soil	724.3	134.7	<LOD	<LOD	769.3	182.7
Glover01	Smelter contam. native soil	377.7	157.3	<LOD	<LOD	67.3	66.7
Glover02	Smelter contam. native soil	472	157.7	<LOD	<LOD	85	70.3
Glover03	Smelter contam. native soil	478	84.3	<LOD	<LOD	105	70.3
Glover04	Smelter contam. native soil	696	98.3	<LOD	<LOD	135.7	121
Glover05	Smelter contam. native soil	1413	123.7	<LOD	<LOD	225	169.3
Leadwood01	Contaminated native soil	57.3	34.3	<LOD	<LOD	35.7	38.3
Leadwood02	Revegetated mine waste	697.7	794.3	<LOD	77.9	973.7	1332.1
Leadwood03	Revegetated mine waste	770	586	<LOD	<LOD	624.3	661.7
Leadwood04	Untreated mine waste	585.3	597.7	<LOD	<LOD	1346.3	1378.3
Leadwood05	Contaminated native soil	89.7	37.7	<LOD	<LOD	119.3	97.7
Leadwood06	Untreated mine waste	560	545	<LOD	<LOD	397.7	836.7
Leadwood07	Revegetated mine waste	525.3	495.7	<LOD	<LOD	635.3	616.7
Leadwood08	Untreated mine waste	916	592	<LOD	<LOD	71.3	46.7
Leadwood09	Contaminated native soil	98.9	55	<LOD	<LOD	100.1	112.3
MoMines 01	Untreated mine waste	16020.3	7512.7	<LOD	<LOD	1899.7	767
MoMines 02	Untreated mine waste	21707	9579.3	ND	<LOD	ND	880.3
MoMines 03	Untreated mine waste	1132.3	1116	<LOD	<LOD	633.3	724.7
Nadist01	Reference bottom	32	15.8	<LOD	<LOD	27.2	27
Nadist02	Reference summit	34	20	<LOD	<LOD	24.8	27.9
Nadist03	Reference bottom	40.2	17.2	<LOD	<LOD	27.6	24
Nadist04	Reference summit	33.2	12.2	<LOD	<LOD	28.9	20.9
Nadist05	Reference bottom	57.7	12.5	<LOD	<LOD	36.2	21.5
Nadist06	Reference summit	30	20	<LOD	<LOD	26	22.7
Nadist07	Reference bottom	24.3	43.3	<LOD	<LOD	24.7	36.7
Nationa01	Untreated mine waste	1635.7	1738.7	<LOD	<LOD	391	737
National02	Untreated mine waste	2532.7	2264.7	50.3	79	1975.7	1800.3
National03	Untreated mine waste	3692.7	3280.7	<LOD	<LOD	541.3	364.7
National04	Contaminated native soil	3249.3	3679.3	<LOD	74.3	849.7	852
National05	Contaminated native soil	1768.7	2721	<LOD	<LOD	615.7	638.3
StJoe01	Reference summit	41.2	30.8	<LOD	<LOD	29.2	38.3

Plot name	Site type	Mean Pb (mg/kg)		Mean Cd (mg/kg)		Mean Zn (mg/kg)	
		Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
StJoe03	Reference bottom	157.1	149.9	<LOD	<LOD	109.4	105
StJoe04	Reference summit	50.2	43.6	<LOD	<LOD	49.4	63.7
StJoe06	Reference summit	53.5	39.4	<LOD	<LOD	42	33.4
StJoe07	Reference bottom	105.3	102.3	<LOD	<LOD	88	89.5
StJoe08	Reference bottom	139.9	112.8	<LOD	<LOD	109.8	96.5
StJoe09	Contaminated native soil	554.9	221.8	<LOD	<LOD	123.1	81.2
StJoe10	Contaminated native soil	405.2	120.8	<LOD	<LOD	70.4	34.6
StJoe11	Contaminated native soil	272	133.8	<LOD	<LOD	88.8	70.3
StJoe12	Untreated mine waste	840.4	850.9	<LOD	<LOD	190.9	163.7
StJoe13	Untreated mine waste	3885.2	2769.1	<LOD	<LOD	1236.8	713
StJoe14	Untreated mine waste	1751.4	1091.4	<LOD	<LOD	364.7	265.8
StJoe15	Untreated mine waste	721.4	920.8	<LOD	<LOD	157.3	102.8
StJoe16	Revegetated mine waste	998.3	649.9	<LOD	<LOD	374.8	253.9
StJoe17	Revegetated mine waste	922.9	889.2	<LOD	<LOD	335.5	462.5
StJoe18	Revegetated mine waste	969.4	739.9	<LOD	<LOD	768	457.1
StJoe19	Revegetated mine waste	1008.4	562.4	<LOD	<LOD	869.6	809.9
StJoe20	Revegetated mine waste	898.8	935.3	<LOD	<LOD	424.5	580.8
StJoe21	Untreated mine waste	838.7	790.9	<LOD	<LOD	344.6	186.7
StJoe22	Untreated mine waste	902.3	930	<LOD	81.7	1363.7	1116
StJoe23	Untreated mine waste	1889	907	<LOD	<LOD	1504.3	1042.3
StJoe24	Untreated mine waste	1061.7	709.3	53.7	<LOD	982.3	562.7
StJoe25	Untreated mine waste	579	606.3	<LOD	<LOD	422.3	229.3
StJoe26	Revegetated mine waste	1075	1212.3	<LOD	<LOD	230	212.7
StJoe29	Revegetated mine waste	840	673	<LOD	<LOD	379.3	380.7
StJoe30	Contaminated native soil	178	50.3	<LOD	<LOD	62.3	45.3
StJoe31	Contaminated native soil	212.7	93.3	<LOD	<LOD	98	78.7
StJoe32	Contaminated native soil	334.7	134.7	<LOD	<LOD	134	102
StJoe33	Contaminated native soil	244.3	69.7	<LOD	<LOD	104.7	73
StJoe34	Contaminated native soil	190.3	38.3	<LOD	<LOD	58.7	38
StJoe35	Contaminated native soil	176.7	75.3	<LOD	<LOD	53.7	39
Sweetwater01	Contaminated native soil	97.3	19.7	<LOD	<LOD	98.7	31.3
Sweetwater 02	Untreated mine waste	2247	1372.7	<LOD	<LOD	1562.7	1207
Sweetwater 03	Untreated mine waste	289	281.3	89.7	<LOD	926.7	1330.7
Sweetwater 04	Untreated mine waste	180.7	309.3	<LOD	<LOD	322.7	413
Sweetwater 05	Contaminated native soil	88	22.7	<LOD	<LOD	67	27.3
Sweetwater 06	Untreated mine waste	330	340	50	<LOD	590.7	974
Sweetwater 07	Contaminated native soil	236	35.7	<LOD	<LOD	249.7	41.7
Westfork01	Untreated mine waste	442.3	479	<LOD	<LOD	296.3	283.3
Westfork02	Untreated mine waste	216.2	321.7	<LOD	<LOD	430.4	879.7
Westfork03	Untreated mine waste	370.3	404.7	<LOD	55.3	958	2305.3
Westfork04	Contaminated native soil	35.8	17.7	<LOD	<LOD	46.1	41
Westfork05	Contaminated native soil	93.7	29.7	<LOD	<LOD	126.3	86.3
Yoder01	Untreated mine waste	3721.3	3582	<LOD	<LOD	669	196.7
Yoder02	Untreated mine waste	4793.3	3627.3	<LOD	<LOD	1492.7	681.3
Yoder03	Untreated mine waste	2091	3077	ND	ND	ND	ND

Appendix II. Topsoil and subsoil nutrient data for all plots

ND = No Data

Plot	Type	pH		N.A. (meq/100g)		% Organic matter		Bray I P (kg/hectare)		Ca (kg/hectare)		Mg (kg/hectare)		K (kg/hectare)		CEC (meq/100g)	
		Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub
Desloge01	Remediated mine waste	7.7	7.8	0.0	0.0	0.3	0.2	26.9	1.1	1951.0	1991.4	317.0	333.8	112.0	88.5	5.7	5.8
Desloge02	Contaminated native soil	7.2	7.3	0.0	0.0	1.7	1.1	19.0	15.7	2694.7	1721.4	674.2	469.3	154.6	142.2	8.7	5.8
Desloge03	Remediated mine waste	7.4	7.5	0.0	0.0	0.2	0.2	98.6	39.2	1550.1	1191.7	206.1	236.3	73.9	79.5	4.3	3.6
Desloge04	Remediated mine waste	7.2	7.5	0.0	0.0	0.2	0.2	143.4	4.5	723.5	986.7	147.8	194.9	69.4	77.3	2.2	3.0
Desloge05	Contaminated native soil	7.0	6.8	0.0	0.5	2.4	1.5	7.8	4.5	2483.0	2381.1	816.5	1034.9	188.2	207.2	8.8	9.9
Desloge06	Contaminated native soil	7.2	7.3	0.0	0.0	7.1	4.8	4.5	4.5	6273.1	4972.8	2072.0	1700.2	211.7	183.7	22.0	17.6
Desloge07	Remediated mine waste	7.2	7.6	0.0	0.0	0.7	0.2	255.4	4.5	994.6	1127.8	187.0	188.2	85.1	106.4	3.0	3.3
Desloge09	Remediated mine waste	6.8	7.0	0.0	0.0	0.3	0.1	267.7	34.7	649.6	891.5	119.8	152.3	84.0	56.0	2.0	2.6
Desloge10	Contaminated native soil	7.0	7.3	0.0	0.0	6.1	1.2	28.0	16.8	5103.8	2613.0	972.2	579.0	247.5	174.7	15.3	8.2
Elvins01	Contaminated native soil	7.4	7.3	0.0	0.0	3.5	3.4	2.2	2.2	6620.3	3476.5	1298.1	1274.6	133.3	135.5	19.8	12.7
Elvins02	Contaminated native soil	7.2	7.0	0.0	0.0	6.4	2.5	10.1	2.2	4132.8	2011.5	1068.5	731.4	172.5	128.8	13.4	7.4
Elvins03	Contaminated native soil	7.2	7.0	0.0	0.0	5.4	1.5	7.8	3.4	3539.2	1155.8	798.6	325.9	114.2	108.6	11.0	3.9
Glover01	Smelter contam. native soil	ND	4.1	ND	7.0	ND	2.1	0.0	9.0	0.0	1032.6	0.0	76.2	0.0	160.2	ND	9.8
Glover02	Smelter contam. native soil	5.8	5.5	1.5	2.0	3.5	2.0	3.4	5.6	1877.1	1543.4	525.3	440.2	151.2	118.7	7.8	7.2
Glover03	Smelter contam. native soil	7.2	7.3	0.0	0.0	5.1	2.1	7.8	5.6	2915.4	2037.3	800.8	701.1	398.7	333.8	9.9	7.5
Glover04	Smelter contam. native soil	7.0	ND	0.0	ND	10.1	6.2	4.5	4.5	6513.9	5055.7	2268.0	2147.0	350.6	358.4	23.4	19.7
Glover05	Smelter contam. native soil	4.4	4.2	9.0	7.0	5.5	3.0	15.7	12.3	192.6	48.2	106.4	48.2	169.1	140.0	10.0	7.4
Leadwood01	Contaminated native soil	5.0	4.7	4.5	5.5	2.6	2.0	7.8	2.2	1433.6	1377.6	779.5	1186.1	200.5	268.8	10.8	13.3
Leadwood02	Revegetated mine waste	6.4	7.1	0.0	0.0	0.5	0.3	271.0	109.8	301.3	175.8	110.9	100.8	62.7	63.8	1.2	0.8
Leadwood03	Revegetated mine waste	7.3	7.6	0.0	0.0	0.6	0.2	33.6	6.7	648.5	887.0	124.3	160.2	63.8	43.7	2.	2.6
Leadwood04	Untreated mine waste	7.70	7.7	0.0	0.0	0.3	0.2	13.4	14.6	458.1	905.0	172.5	238.6	41.4	43.7	1.7	3.0
Leadwood05	Contaminated native soil	7.0	6.8	0.0	0.0	2.8	1.5	4.5	3.4	2615.2	2035.0	861.3	1009.1	154.6	163.5	9.2	8.5
Leadwood06	Untreated mine waste	7.6	7.6	0.0	0.0	0.4	0.1	10.1	5.6	850.1	406.6	159.0	121.0	43.7	43.7	2.5	1.4
Leadwood07	Revegetated mine waste	7.4	7.5	0.0	0.0	0.3	0.1	163.5	34.7	181.4	128.8	103.0	95.2	65.0	53.8	0.9	0.7
Leadwood08	Untreated mine waste	7.1	7.5	0.0	0.0	0.2	0.1	5.6	3.4	681.0	638.4	231.8	220.6	52.6	51.5	2.4	2.3
Leadwood09	Contaminated native soil	7.0	ND	0.0	ND	3.3	2.4	2.2	1.1	3259.2	2573.8	1167.0	1218.6	194.9	222.9	11.8	10.5
MoMines01	Untreated mine waste	7.7	7.5	0.0	0.0	0.5	0.2	1.1	1.1	1060.6	3044.2	199.4	302.4	56.0	82.9	3.2	8.0

Plot	Type	pH		N.A. (meq/100g)		% Organic matter		Bray I P (kg/hectare)		Ca (kg/hectare)		Mg (kg/hectare)		K (kg/hectare)		CEC (meq/100g)	
		Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub
MoMines02	Untreated mine waste	ND	7.7	ND	0.0	ND	0.3	0.0	1.1	0.0	1374.2	0.0	234.1	0.0	63.8	ND	4.0
MoMines03	Untreated mine waste	7.3	7.6	0.0	0.0	0.2	0.1	4.5	5.6	862.4	1005.8	217.3	221.8	32.5	29.1	2.8	3.1
Nadist01	Reference bottom	4.4	4.4	9.0	6.0	3.8	1.6	12.3	6.7	722.4	341.6	212.8	165.8	174.7	125.4	11.6	7.5
Nadist02	Reference summit	3.9	4.3	10.5	6.5	3.1	1.2	6.7	4.5	276.6	246.4	82.9	132.2	146.7	131.0	11.6	7.7
Nadist03	Reference bottom	3.8	4.0	14.0	8.5	4.6	1.3	16.8	7.8	502.9	340.5	100.8	98.6	137.8	106.4	15.7	9.7
Nadist04	Reference summit	4.0	4.5	9.5	4.5	2.8	1.0	10.1	10.1	312.5	250.9	117.6	121.0	133.3	100.8	10.8	5.6
Nadist05	Reference bottom	4.0	4.4	14.5	6.0	5.4	1.6	13.4	14.6	605.9	302.4	266.6	166.9	138.9	90.7	17.0	7.4
Nadist06	Reference summit	ND	4.2	ND	4.5	2.9	1.0	0.0	3.4	203.8	80.6	101.9	163.5	105.3	106.4	1.0	5.4
Nadist07	Reference bottom	5.2	ND	5.0	ND	5.7	ND	9.0	0.0	1461.6	0.0	413.3	0.0	154.6	0.0	10.0	ND
Nationa01	Untreated mine waste	7.7	7.4	0.0	0.0	0.4	0.4	3.4	2.2	908.3	1225.3	201.6	263.2	52.6	51.5	2.8	3.8
National02	Untreated mine waste	7.6	7.6	0.0	0.0	0.4	0.4	2.2	2.2	678.7	384.2	230.7	165.8	71.7	63.8	2.5	1.5
National03	Untreated mine waste	7.6	ND	0.0	ND	0.6	ND	1.1	0.0	1135.7	0.0	202.7	0.0	51.5	0.0	3.3	ND
National04	Contaminated native soil	7.1	ND	0.0	ND	2.3	ND	16.8	0.0	2590.6	0.0	516.3	0.0	168.0	0.0	7.9	ND
National05	Contaminated native soil	7.2	7.1	0.0	0.0	2.1	1.1	14.6	12.3	2418.1	991.2	413.3	218.4	131.0	109.8	7.1	3.2
StJoe01	Reference summit	3.9	4.	8.0	10.0	1.7	1.6	7.8	6.7	427.8	393.1	76.2	259.8	145.6	160.2	9.4	12.0
StJoe03	Reference bottom	4.8	5.2	6.0	4.0	2.9	2.1	5.6	3.4	1768.5	1919.7	489.4	597.0	163.5	145.6	12.0	10.7
StJoe04	Reference summit	3.9	3.9	6.5	7.5	1.3	0.7	11.2	6.7	293.4	405.4	103.0	269.9	124.3	124.3	7.7	9.6
StJoe06	Reference summit	3.9	3.9	7.0	9.0	1.5	1.0	10.1	20.2	266.6	319.2	112.0	174.7	112.0	127.7	8.1	10.5
StJoe07	Reference bottom	5.7	5.5	2.0	2.5	2.4	1.4	13.4	10.1	2069.8	1509.8	347.2	353.9	201.6	161.3	8.1	7.4
StJoe08	Reference bottom	5.4	5.4	5.5	3.5	3.9	2.2	17.9	7.8	2796.6	2096.6	600.3	502.9	245.3	149.0	14.3	10.2
StJoe09	Contaminated native soil	7.2	7.0	0.0	0.0	2.5	1.3	3.4	3.4	2786.6	1859.2	597.0	519.7	155.7	134.4	8.6	6.2
StJoe10	Contaminated native soil	7.5	7.0	0.0	0.0	2.4	1.6	3.4	1.1	3591.8	2909.8	1095.4	1221.9	199.4	226.2	12.3	11.3
StJoe11	Contaminated native soil	7.3	6.8	0.0	0.0	1.9	0.9	3.4	1.1	2604.0	1348.5	517.4	452.5	124.3	118.7	7.9	4.8
StJoe12	Untreated mine waste	7.7	7.2	0.0	0.0	0.3	0.3	21.3	3.4	946.4	768.3	191.5	171.4	37.0	37.0	2.9	2.4
StJoe13	Untreated mine waste	7.4	7.6	0.0	0.0	0.4	0.2	25.8	16.8	691.0	560.0	144.5	118.7	39.2	43.7	2.1	1.7
StJoe14	Untreated mine waste	7.6	7.6	0.0	0.0	0.4	0.3	28.0	3.4	1215.2	1230.9	258.7	198.2	41.4	39.2	3.7	3.5
StJoe15	Untreated mine waste	7.7	7.8	0.0	0.0	0.1	0.4	4.5	1.1	1040.5	2224.3	252.0	268.8	53.8	34.7	3.3	6.0
StJoe16	Revegetated mine waste	7.5	7.7	0.0	0.0	1.8	0.2	6.7	2.2	2109.0	1645.3	412.2	236.3	63.8	37.0	6.3	4.6
StJoe17	Revegetated mine waste	7.5	7.8	0.0	0.0	1.5	0.1	12.3	1.1	1712.5	1689.0	361.8	280.0	70.6	40.3	5.2	4.9
StJoe18	Revegetated mine waste	7.8	7.7	0.0	0.0	0.5	0.1	25.8	2.2	3896.5	1997.0	946.4	636.2	107.5	60.5	12.3	6.9
StJoe19	Revegetated mine waste	7.6	7.6	0.0	0.0	0.6	0.2	20.2	5.6	1077.4	872.5	181.4	150.1	45.9	32.5	3.1	2.5
StJoe20	Revegetated mine waste	7.5	7.6	0.0	0.0	1.9	0.1	10.1	2.2	1970.1	1798.7	427.8	255.4	84.0	44.8	6.1	5.0
StJoe21	Untreated mine waste	7.4	7.6	0.0	0.0	0.4	0.3	14.6	1.1	1042.7	1015.8	208.3	206.1	52.6	37.0	3.2	3.1

Plot	Type	pH		N.A. (meq/100g)		% Organic matter		Bray I P (kg/hectare)		Ca (kg/hectare)		Mg (kg/hectare)		K (kg/hectare)		CEC (meq/100g)	
		Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub
StJoe22	Untreated mine waste	7.6	7.5	0.0	0.0	0.1	0.1	6.7	7.8	778.4	805.3	188.2	181.4	49.3	39.2	2.5	2.5
StJoe23	Untreated mine waste	7.6	7.7	0.0	0.0	0.4	0.6	57.1	14.6	642.9	609.3	164.6	166.9	42.6	39.2	2.1	2.0
StJoe24	Untreated mine waste	7.8	7.6	0.0	0.0	0.1	0.1	15.7	4.5	887.0	1041.6	190.4	237.4	41.4	53.8	2.7	3.3
StJoe25	Untreated mine waste	7.8	7.6	0.0	0.0	0.2	0.1	15.7	4.5	689.9	1037.1	154.6	207.2	50.4	43.7	2.2	3.1
StJoe26	Revegetated mine waste	7.7	7.8	0.0	0.0	0.8	0.3	4.5	1.1	2029.4	2711.5	315.8	375.2	59.4	48.2	5.8	7.5
StJoe29	Revegetated mine waste	7.6	7.6	0.0	0.0	0.1	0.2	7.8	2.2	1047.2	1034.9	189.3	181.4	25.8	40.3	3.1	3.0
StJoe30	Contaminated native soil	7.1	6.9	0.0	0.0	1.9	0.9	4.5	2.2	2261.3	1830.1	623.8	657.4	152.3	127.7	7.5	6.7
StJoe31	Contaminated native soil	7.1	6.9	0.0	0.0	2.8	1.7	7.8	6.7	3233.4	2381.1	779.5	620.5	206.1	180.3	10.4	7.8
StJoe32	Contaminated native soil	7.1	7.0	0.0	0.0	2.9	1.4	6.7	3.4	3048.6	1895.0	757.1	520.8	160.2	122.1	9.8	6.3
StJoe33	Contaminated native soil	7.2	7.0	0.0	0.0	3.2	1.1	6.7	5.6	3400.3	1534.4	721.3	385.3	189.3	155.7	10.5	5.0
StJoe34	Contaminated native soil	6.9	6.6	0.0	0.5	2.1	0.8	4.5	1.1	2721.6	2094.4	905.0	1141.3	226.2	216.2	9.7	9.7
StJoe35	Contaminated native soil	6.1	5.9	2.0	2.0	3.2	1.7	4.5	3.4	2832.5	2347.5	1135.7	1288.0	238.6	226.2	12.8	12.3
Sweetwater01	Contaminated native soil	7.2	6.6	0.0	0.5	3.4	1.1	15.7	9.0	2814.6	980.0	717.9	312.5	131.0	93.0	9.1	4.0
Sweetwater02	Untreated mine waste	ND	7.3	ND	0.0	ND	0.2	0.0	3.4	0.0	702.2	0.0	239.7	0.0	24.6	ND	2.5
Sweetwater03	Untreated mine waste	7.5	7.5	0.0	0.0	0.3	0.2	4.5	4.5	207.2	207.2	149.0	151.2	23.5	21.3	1.0	1.0
Sweetwater04	Untreated mine waste	7.6	7.7	0.0	0.0	0.1	0.1	2.2	2.2	141.1	869.1	119.8	314.7	23.5	28.0	0.8	3.1
Sweetwater05	Contaminated native soil	6.9	6.2	0.0	0.5	3.8	1.4	5.6	4.5	3156.2	817.6	1006.9	463.7	97.4	79.5	10.9	4.1
Sweetwater06	Untreated mine waste	7.5	7.5	0.0	0.0	0.1	0.2	5.6	4.5	412.2	330.4	198.2	162.4	28.0	22.4	1.7	1.4
Sweetwater07	Contaminated native soil	7.2	6.6	0.0	0.5	4.6	2.5	7.8	5.6	3921.1	1703.5	941.9	534.2	114.2	116.5	12.4	6.4
Westfork01	Untreated mine waste	7.3	7.5	0.0	0.0	0.4	0.3	3.4	3.4	482.7	453.6	198.2	282.2	23.5	19.0	1.8	2.1
Westfork02	Untreated mine waste	7.3	7.3	0.0	0.0	0.3	0.3	6.7	4.5	34.7	23.5	110.9	93.0	22.4	25.8	0.5	0.4
Westfork03	Untreated mine waste	7.5	7.4	0.0	0.0	0.3	0.4	3.4	3.4	105.3	30.2	145.6	89.6	22.4	17.9	0.8	0.4
Westfork04	Contaminated native soil	7.7	6.1	0.0	1.0	0.4	1.9	2.2	6.7	901.6	651.8	152.3	482.7	45.9	153.4	2.6	4.4
Westfork05	Contaminated native soil	7.0	7.0	0.0	0.0	3.5	2.5	11.2	11.2	3645.6	2657.8	954.2	818.7	281.1	216.2	12.0	9.2
Yoder01	Untreated mine waste	7.6	7.7	0.0	0.0	0.8	0.3	4.5	5.6	1945.4	1509.8	373.0	369.6	163.5	160.2	5.9	4.9
Yoder02	Untreated mine waste	7.6	7.5	0.0	0.0	0.5	0.5	1.1	3.4	1719.2	1358.6	327.0	262.1	152.3	142.2	5.2	4.2
Yoder03	Untreated mine waste	ND	ND	ND	ND	ND	ND	26.9	1.1	1951.0	1991.4	317.0	333.8	112.0	88.5	ND	ND

Appendix III. Floristic metrics for all plots.

ND = Missing Data

Plot Name	Site Type	Species Richness	Number of Exotic Species	Number of Native Species	Exotic to Native Species Ratio	Exotic Species Cover (%)	Native Species Cover (%)	Exotic to Native Cover Ratio	Mean C	FQI
Desloge01	Remediated mine waste	24	5	19	0.26	39	26	1.50	2.95	12.85
Desloge02	Contaminated native soil	80	6	74	0.08	12	243	0.05	3.43	29.53
Desloge03	Remediated mine waste	34	21	13	1.62	68	36	1.89	2.46	8.88
Desloge04	Remediated mine waste	37	18	19	0.95	75	42	1.79	2.05	8.95
Desloge05	Contaminated native soil	77	0	77	0.00	0	196	0.00	4.35	38.18
Desloge06	Contaminated native soil	136	0	136	0.00	0	232	0.00	4.52	52.74
Desloge07	Remediated mine waste	28	13	15	0.87	106	27	3.93	2.33	9.04
Desloge09	Remediated mine waste	31	15	16	0.94	102	32	3.19	2.63	10.50
Desloge10	Contaminated native soil	48	4	44	0.09	4	260	0.02	3.41	22.61
Elvins01	Contaminated native soil	66	3	63	0.05	3	157	0.02	4.40	34.90
Elvins02	Contaminated native soil	58	0	58	0.00	0	226	0.00	3.98	30.33
Elvins03	Contaminated native soil	59	1	58	0.02	1	188	0.01	4.41	33.61
Glover01	Smelter contam. native soil	79	0	79	0.00	0	195	0.00	4.78	42.53
Glover02	Smelter contam. native soil	108	1	107	0.01	1	244	0.00	4.31	44.57
Glover03	Smelter contam. native soil	84	0	84	0.00	0	255	0.00	4.42	40.48
Glover04	Smelter contam. native soil	77	0	77	0.00	0	203	0.00	4.19	36.81
Glover05	Smelter contam. native soil	61	0	61	0.00	0	175	0.00	4.80	37.51
Leadwood01	Contaminated native soil	57	2	55	0.04	4	170	0.02	4.24	31.42
Leadwood02	Revegetated mine waste	12	3	9	0.33	19	77	0.25	2.89	8.67
Leadwood03	Revegetated mine waste	32	6	26	0.23	19	70	0.27	3.27	16.67
Leadwood04	Untreated mine waste	2	0	2	0.00	0	2	0.00	1.50	2.12
Leadwood05	Contaminated native soil	63	0	63	0.00	0	249	0.00	4.10	32.50
Leadwood06	Untreated mine waste	22	6	16	0.38	7	18	0.39	3.06	12.25

Plot Name	Site Type	Species Richness	Number of Exotic Species	Number of Native Species	Exotic to Native Species Ratio	Exotic Species Cover (%)	Native Species Cover (%)	Exotic to Native Cover Ratio	Mean C	FQI
Leadwood07	Revegetated mine waste	19	9	10	0.90	30	33	0.91	2.70	8.54
Leadwood08	Untreated mine waste	14	2	12	0.17	2	14	0.14	4.42	15.30
Leadwood09	Contaminated native soil	81	0	81	0.00	0	224	0.00	4.22	38.00
MoMines01	Untreated mine waste	6	2	4	0.50	2	4	0.50	4.00	8.00
MoMines02	Untreated mine waste	6	4	2	2.00	4	2	2.00	2.50	3.54
MoMines03	Untreated mine waste	6	3	3	1.00	3	4	0.75	4.00	6.93
Nadist01	Reference bottom	99	3	96	0.03	3	267	0.01	4.44	43.48
Nadist02	Reference summit	58	0	58	0.00	0	193	0.00	4.78	36.37
Nadist03	Reference bottom	83	0	83	0.00	0	261	0.00	4.75	43.25
Nadist04	Reference summit	53	0	53	0.00	0	205	0.00	4.64	33.79
Nadist05	Reference bottom	100	0	100	0.00	0	369	0.00	4.64	46.40
Nadist06	Reference summit	66	0	66	0.00	0	234	0.00	4.62	37.54
Nadist07	Reference bottom	80	0	80	0.00	0	235	0.00	4.80	42.93
Nationa01	Untreated mine waste	18	4	14	0.29	5	16	0.31	3.43	12.83
National02	Untreated mine waste	10	3	7	0.43	3	7	0.43	3.43	9.07
National03	Untreated mine waste	23	4	19	0.21	6	42	0.14	3.37	14.68
National04	Contaminated native soil	68	9	59	0.15	98	175	0.56	3.63	27.86
National05	Contaminated native soil	73	4	69	0.06	7	231	0.03	3.30	27.45
StJoe01	Reference summit	50	0	50	0.00	0	183	0.00	4.82	34.08
StJoe03	Reference bottom	132	0	132	0.00	0	210	0.00	4.30	49.35
StJoe04	Reference summit	50	0	50	0.00	0	122	0.00	4.48	31.68
StJoe06	Reference summit	66	0	66	0.00	0	110	0.00	4.47	36.31
StJoe07	Reference bottom	106	1	105	0.01	1	206	0.00	3.93	40.30
StJoe08	Reference bottom	105	3	102	0.03	3	216	0.01	4.02	40.60
StJoe09	Contaminated native soil	85	2	83	0.02	3	154	0.02	4.39	39.95
StJoe10	Contaminated native soil	99	1	98	0.01	1	190	0.01	4.29	42.43
StJoe11	Contaminated native soil	77	0	77	0.00	0	185	0.00	4.55	39.89

Plot Name	Site Type	Species Richness	Number of Exotic Species	Number of Native Species	Exotic to Native Species Ratio	Exotic Species Cover (%)	Native Species Cover (%)	Exotic to Native Cover Ratio	Mean C	FQI
StJoe12	Untreated mine waste	14	6	8	0.75	6	8	0.75	1.50	4.24
StJoe13	Untreated mine waste	29	7	22	0.32	8	27	0.30	3.45	16.20
StJoe14	Untreated mine waste	12	4	8	0.50	4	20	0.20	2.50	7.07
StJoe15	Untreated mine waste	18	0	18	0.00	0	23	0.00	3.39	14.38
StJoe16	Revegetated mine waste	47	10	37	0.27	11	126	0.09	3.46	21.04
StJoe17	Revegetated mine waste	32	6	26	0.23	15	107	0.14	4.04	20.59
StJoe18	Revegetated mine waste	17	3	14	0.21	4	50	0.08	3.64	13.63
StJoe19	Revegetated mine waste	23	3	20	0.15	5	93	0.05	3.35	14.98
StJoe20	Revegetated mine waste	37	5	32	0.16	8	121	0.07	3.59	20.33
StJoe21	Untreated mine waste	44	6	38	0.16	6	51	0.12	3.42	21.09
StJoe22	Untreated mine waste	12	2	10	0.20	2	10	0.20	3.00	9.49
StJoe23	Untreated mine waste	12	2	10	0.20	2	15	0.13	3.40	10.75
StJoe24	Untreated mine waste	5	1	4	0.25	1	5	0.20	2.50	5.00
StJoe25	Untreated mine waste	8	2	6	0.33	2	12	0.17	3.67	8.98
StJoe26	Revegetated mine waste	40	9	31	0.29	12	126	0.10	3.52	19.58
StJoe29	Revegetated mine waste	35	6	29	0.21	22	82	0.27	3.52	18.94
StJoe30	Contaminated native soil	70	1	69	0.01	1	157	0.01	4.29	35.63
StJoe31	Contaminated native soil	48	1	47	0.02	1	139	0.01	4.47	30.63
StJoe32	Contaminated native soil	68	1	67	0.01	1	175	0.01	4.52	37.02
StJoe33	Contaminated native soil	68	1	67	0.01	1	191	0.01	4.54	37.14
StJoe34	Contaminated native soil	70	0	70	0.00	0	186	0.00	4.29	35.86
StJoe35	Contaminated native soil	74	0	74	0.00	0	168	0.00	4.19	36.04
Sweetwater01	Contaminated native soil	82	1	81	0.01	1	216	0.00	4.57	41.11
Sweetwater02	Untreated mine waste	1	0	1	0.00	0	1	0.00	5.00	5.00
Sweetwater03	Untreated mine waste	0	0	0	ND	0	ND	ND	0.00	0.00
Sweetwater04	Untreated mine waste	2	0	2	0.00	0	2	0.00	2.50	3.54
Sweetwater05	Contaminated native soil	76	0	76	0.00	0	222	0.00	4.61	40.15

Plot Name	Site Type	Species Richness	Number of Exotic Species	Number of Native Species	Exotic to Native Species Ratio	Exotic Species Cover (%)	Native Species Cover (%)	Exotic to Native Cover Ratio	Mean C	FQI
Sweetwater06	Untreated mine waste	2	0	2	0.00	0	2	0.00	3.50	4.95
Sweetwater07	Contaminated native soil	69	1	68	0.01	1	262	0.00	4.69	38.68
Westfork01	Untreated mine waste	16	2	14	0.14	2	16	0.13	2.57	9.62
Westfork02	Untreated mine waste	6	1	5	0.20	1	5	0.20	3.40	7.60
Westfork03	Untreated mine waste	0	0	0	ND	0	ND	ND	0.00	0.00
Westfork04	Contaminated native soil	68	0	68	0.00	0	170	0.00	4.59	37.84
Westfork05	Contaminated native soil	78	0	78	0.00	0	255	0.00	4.87	43.03
Yoder01	Untreated mine waste	35	15	20	0.75	21	24	0.88	2.60	11.63
Yoder02	Untreated mine waste	41	12	29	0.41	14	33	0.42	2.86	15.41
Yoder03	Untreated mine waste	20	9	11	0.82	11	14	0.79	1.55	5.13

Appendix IV. Species C value and frequency by site.

Species with no C value are not native to Missouri.

			Site (number of plots)										
Scientific Name	Common Name	C value	Desloge (9)	Elvins (3)	Glover (5)	Leadwood (9)	Missouri Mines (3)	Nadist (7)	National (5)	St. Joe (31)	Sweetwater (7)	West Fork (5)	Yoder (3)
Acalypha gracilens	slender threeseed mercury	3	-	0.33	-	-	-	-	-	-	-	-	-
Acalypha virginica	virginia threeseed mercury	2	-	-	0.4	-	-	-	0.2	-	-	-	-
Acer negundo	boxelder	1	0.22	-	-	-	-	-	0.4	-	-	-	-
Acer rubrum	red maple	6	-	-	0.4	-	-	1	-	0.13	0.43	0.4	-
Acer saccharinum	silver maple	1	0.22	-	-	-	-	-	0.2	-	-	0.2	-
Acer saccharum	sugar maple	5	0.22	0.33	1	0.33	-	-	0.4	0.35	-	0.4	-
Achillea millefolium	common yarrow	1	0.22	-	-	-	-	-	-	0.03	-	-	-
Adiantum pedatum	northern maidenhair	6	-	-	-	-	-	-	-	-	-	0.2	-
Aesculus glabra	ohio buckeye	5	-	-	0.6	0.11	-	-	-	-	-	0.2	-
Agalinis tenuifolia	slenderleaf false foxglove	4	-	-	-	0.11	-	-	-	0.19	-	-	-
Agave virginica	false aloe	7	0.11	0.33	-	0.11	-	-	-	-	-	-	-
Agrimonia rostellata	beaked agrimony	3	0.22	-	0.6	0.33	-	0.14	-	0.29	-	0.2	-
Agropyron cristatum	crested wheatgrass		-	-	-	0.11	-	-	-	-	-	-	-
Agrostis gigantea	redtop		0.22	-	-	-	-	-	-	0.13	-	-	-
Ailanthus altissima	tree of heaven		-	-	-	-	0.33	-	0.2	-	-	-	-
Allium canadense	meadow garlic	1	0.22	0.67	-	-	-	-	-	0.13	-	-	-
Allium vineale	wild garlic		0.11	-	-	-	-	-	-	-	-	-	-
Amaranthus tuberculatus	rough fruit amaranth	2	0.22	-	-	0.11	-	-	-	-	-	-	-
Ambrosia artemisiifolia	annual ragweed	0	0.67	-	0.2	0.44	-	0.29	0.2	0.29	-	0.2	1
Ambrosia trifida	great ragweed	0	0.56	-	-	-	-	-	0.2	-	-	-	0.33
Amelanchier arborea	common serviceberry	6	0.11	0.33	0.2	0.11	-	0.86	-	0.26	0.29	0.2	-
Amorpha canescens	leadplant	8	-	0.33	-	-	-	-	-	-	-	-	-
Ampelopsis cordata	heartleaf peppervine	4	-	-	-	-	-	-	0.2	-	-	-	-
Amphicarpaea bracteata	american hogpeanut	4	0.22	0.33	0.6	0.22	-	0.86	0.2	0.42	0.29	0.2	-
Andropogon gerardii	big bluestem	5	0.11	0.33	-	0.22	-	-	-	0.16	-	-	-
Andropogon scoparius	little bluestem	5	0.11	-	-	-	-	-	-	0.03	-	-	-
Anemone virginiana	tall thimbleweed	4	0.33	-	0.4	0.11	-	0.14	-	0.06	0.14	-	-
Anemonella thalictroides	rue anemone	5	0.22	-	0.2	-	-	0.57	-	0.16	-	-	-
Angelica venenosa	hairy angelica	7	0.11	-	-	-	-	0.57	-	0.03	0.43	-	-
Antennaria plantaginifolia	woman`s tobacco	5	0.22	0.33	-	-	-	0.71	-	0.39	0.29	0.2	-
Apios americana	groundnut	6	-	-	-	-	-	-	0.2	-	-	-	-
Apocynum cannabinum	indianhemp	3	0.33	-	0.2	0.11	-	0.14	-	0.35	-	-	-
Arabis canadensis	sicklepod	4	0.22	0.33	0.2	-	-	-	-	0.16	-	-	0.33
Arabis laevigata	smooth rockcress	5	0.11	-	-	-	-	-	-	0.03	-	-	-
Arenaria patula	pitcher`s stitchwort	7	-	0.33	-	-	-	-	-	-	-	-	-
Arenaria serpyllifolia	thymeleaf sandwort		0.11	0.33	-	-	-	-	-	0.16	-	-	0.33
Arenaria stricta	michaux`s stitchwort	9	-	0.33	-	-	-	-	-	-	-	-	-

			Site (number of plots)										
Scientific Name	Common Name	C value	Desloge (9)	Elvins (3)	Glover (5)	Leadwood (9)	Missouri Mines (3)	Nadist (7)	National (5)	St. Joe (31)	Sweetwater (7)	West Fork (5)	Yoder (3)
Arisaema atrorubens	jack in the pulpit	6	0.11	-	0.2	-	-	-	-	-	-	0.2	-
Arisaema dracontium	green dragon	6	0.11	-	0.4	0.11	-	-	0.4	0.03	-	-	-
Aristida purpurascens	arrowfeather threeawn	5	-	-	-	0.11	-	-	-	-	-	-	-
Aristolochia serpentaria	virginia snakeroot	6	0.22	-	0.6	0.33	-	1	-	0.35	0.29	0.4	-
Aristolochia tomentosa	woolly dutchman`s pipe	7	0.11	-	-	-	-	-	-	-	-	-	-
Aruncus dioicus var. pubescens	bride's veil	6	-	-	0.2	-	-	-	-	-	-	0.2	-
Asarum canadense	canadian wildginger	6	0.33	-	0.4	-	-	-	0.2	-	-	0.2	-
Asclepias purpurascens	purple milkweed	6	-	-	-	-	0.33	-	-	-	-	-	-
Asclepias quadrifolia	fourleaf milkweed	6	0.22	-	0.4	0.11	-	0.71	-	0.23	-	0.2	-
Asclepias tuberosa	butterfly milkweed	5	-	-	-	-	-	-	-	0.03	-	-	-
Asclepias verticillata	whorled milkweed	2	0.11	0.33	-	0.11	-	-	0.4	0.06	-	-	-
Asclepias viridiflora	green comet milkweed	9	0.11	-	-	-	-	-	-	-	-	-	-
Asclepias viridis	green antelopehorn	6	-	-	-	-	-	-	-	0.13	-	-	-
Ascyrum hypericoides	st. andrew`s cross	8	0.11	-	-	-	-	0.29	-	0.03	0.29	-	-
Asimina triloba	pawpaw	5	0.33	-	0.8	-	-	-	0.4	-	-	0.4	-
Asparagus officinalis	garden asparagus		-	0.33	-	-	-	-	-	0.03	-	-	-
Asplenium platyneuron	ebony spleenwort	4	-	-	0.4	0.11	-	0.14	-	0.13	-	-	-
Aster azureus	skyblue aster	7	0.11	0.67	-	0.11	-	-	-	0.03	-	-	-
Aster laevis	smooth blue aster	7	-	-	-	-	-	-	-	0.03	-	-	-
Aster lateriflorus	calico aster	3	0.11	0.33	0.2	-	-	0.14	0.2	0.1	-	-	-
Aster novae-angliae	new england aster	4	-	-	-	0.11	-	-	-	-	-	-	-
Aster pilosus	hairy white oldfield aster	0	-	-	-	0.11	-	-	0.2	0.03	-	0.2	0.67
Aster turbinellus	smooth violet prairie aster	6	-	-	0.2	0.11	-	0.71	-	0.13	-	0.2	-
Avena sativa	common oat		0.11	-	-	-	-	-	-	-	-	-	-
Bidens aristosa	bearded beggarticks	1	0.22	-	0.2	-	-	-	0.2	-	-	0.2	0.33
Bidens bipinnata	spanish needles		0.11	-	-	-	-	-	-	-	-	-	-
Blephilia ciliata	downy pagoda-plant	5	0.11	-	0.4	0.11	-	-	-	0.03	-	-	-
Boehmeria cylindrica	smallspike false nettle	4	-	-	-	-	-	-	0.4	-	-	0.2	-
Botrychium virginianum	rattlesnake fern	4	0.22	-	0.4	0.22	-	0.14	0.2	0.32	-	0.2	-
Bouteloua curtipendula	sideoats grama	7	-	0.33	-	0.22	-	-	0.2	0.03	-	-	0.33
Brachyelytrum erectum	bearded shorthusk	6	-	-	1	-	-	0.57	-	0.19	0.14	0.2	-
Bromus hordeaceus	soft brome		0.22	-	-	-	-	-	-	-	-	-	-
Bromus inermis	smooth brome		0.56	-	-	0.22	-	-	-	0.03	-	-	-
Bromus japonicus	japanese brome		0.22	-	-	-	-	-	-	-	-	-	-
Bromus pubescens	hairy woodland brome	5	0.22	0.33	0.6	0.22	-	0.29	-	0.26	0.29	-	-
Bromus squarrosus	corn brome		0.44	-	-	-	-	-	-	0.1	-	-	1
Bromus tectorum	cheatgrass		0.33	-	-	-	-	-	-	0.03	-	-	-
Cacalia atriplicifolia	pale indian plaintain	4	0.11	-	0.8	-	-	0.14	-	0.1	-	-	-
Cacalia muehlenbergii	great indian plaintain	6	-	-	0.2	-	-	-	-	-	-	0.2	-
Calycocarpum lyonii	cupseed	6	-	-	-	-	-	-	0.2	-	-	-	-
Calystegia sepium	hedge false bindweed	1	-	-	-	-	-	-	0.2	-	-	-	-
Campanula americana	american bellflower	4	0.11	-	0.2	-	-	-	0.4	-	-	0.2	-

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Campsis radicans	trumpet creeper	3	0.33	-	0.2	-	-	-	0.4	-	-	-	-
Camptosorus rhizophyllus	walking fern	7	-	-	-	-	-	-	-	-	-	0.2	-
Carduus nutans	musk thistle		0.11	-	-	-	-	-	-	-	-	-	-
Carex amphibola	eastern narrowleaf sedge	3	0.11	-	0.8	0.22	-	-	-	0.06	-	-	-
Carex artitecta	whitetinge sedge	6	0.22	1	0.4	-	-	0.71	-	0.35	-	-	-
Carex blanda	eastern woodland sedge	3	0.22	-	0.4	-	-	-	0.4	0.13	-	0.2	-
Carex cephalophora	oval-leaf sedge	5	0.11	0.67	-	0.11	-	0.29	-	0.29	-	0.2	-
Carex complanata	hirsute sedge	9	0.11	0.33	0.2	0.11	-	0.71	-	0.26	-	0.2	-
Carex digitalis	slender woodland sedge	8	-	-	-	-	-	0.14	-	0.06	-	-	-
Carex festucacea	fescue sedge	5	0.33	-	-	-	-	-	-	-	-	-	-
Carex glaucodea	blue sedge	4	-	-	-	-	-	0.14	-	0.16	-	-	-
Carex granularis	limestone meadow sedge	4	-	-	-	-	-	-	-	0.03	-	-	-
Carex jamesii	james` sedge	5	-	-	-	-	-	-	-	0.06	-	-	-
Carex molesta	troublesome sedge	4	-	-	-	-	-	-	-	0.03	-	-	-
Carex muehlenbergii	muhlenberg`s sedge	5	-	-	-	-	-	0.14	-	0.19	-	-	-
Carex nigromarginata	black edge sedge	10	-	-	0.4	0.33	-	0.71	-	0.06	0.29	0.4	-
Carex normalis	greater straw sedge	4	-	-	-	-	-	-	-	0.03	-	-	-
Carex planispicata	flat-spiked sedge	8	0.11	-	-	-	-	-	-	0.03	-	-	-
Carex retroflexa	reflexed sedge	4	0.22	0.33	0.2	0.22	-	0.14	-	0.23	-	0.2	-
Carex rosea	rosy sedge	4	-	-	-	-	-	0.14	-	-	-	-	-
Carex umbellata	parasol sedge	6	-	-	0.2	0.11	-	0.14	-	0.16	-	-	-
Carpinus caroliniana	american hornbeam	6	-	-	0.8	-	-	-	0.2	-	-	0.2	-
Carya cordiformis	bitternut hickory	5	0.11	-	0.6	0.11	-	0.14	-	-	0.14	0.2	-
Carya glabra	pignut hickory	8	-	-	0.2	0.22	-	-	-	0.16	0.14	0.2	-
Carya ovata	shagbark hickory	4	-	-	-	0.11	-	-	0.2	0.06	-	-	-
Carya texana	black hickory	5	0.11	0.67	0.4	0.22	-	0.57	-	0.39	0.43	0.2	-
Carya tomentosa	mockernut hickory	5	0.11	0.33	0.6	0.11	-	1	-	0.29	0.43	0.2	-
Cassia fasciculata	sleepingplant	1	0.22	-	0.2	0.11	-	-	-	-	-	-	0.33
Cassia nictitans	partridge pea	2	-	-	-	-	-	-	-	0.06	-	-	-
Catalpa speciosa	northern catalpa	2	-	-	-	-	-	-	0.2	-	-	-	-
Ceanothus americanus	new jersey tea	7	-	-	0.2	-	-	-	-	0.06	0.43	-	-
Celastrus scandens	american bittersweet	3	0.22	1	0.2	0.33	-	0.14	0.2	0.26	0.14	0.4	-
Celtis occidentalis	common hackberry	4	0.33	0.33	0.4	0.22	0.33	0.29	0.2	0.32	0.29	0.2	-
Celtis tenuifolia	dwarf hackberry	6	0.22	0.33	0.2	0.11	-	-	-	0.29	-	-	-
Centaurea maculosa	spotted knapweed		0.11	-	-	-	-	-	0.4	-	-	-	0.67
Cephalanthus occidentalis	common buttonbush	3	-	-	0.2	-	-	-	-	-	-	-	-
Cerastium brachypodum	shortstalk chickweed	2	-	-	-	-	-	-	-	0.06	-	-	-
Cerastium semidecandrum	fivestamen chickweed		0.11	-	-	-	-	-	-	-	-	-	-
Cercis canadensis	eastern redbud	3	0.11	1	0.8	0.33	-	-	0.4	0.32	-	0.4	-
Chasmanthium latifolium	indian woodoats	4	0.11	-	0.4	-	-	-	0.2	0.06	-	-	-
Chenopodium album	lambsquarters		0.33	-	-	0.11	-	-	-	-	-	-	0.33

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Chenopodium pallescens	slimleaf goosefoot	2	-	-	-	0.11	-	-	-	-	-	-	-
Chrysanthemum leucanthemum	oxeye daisy		-	-	-	-	-	-	-	-	-	-	0.33
Cimicifuga racemosa	black bugbane	7	-	-	0.8	-	-	-	-	0.03	-	0.2	-
Cirsium carolinianum	soft thistle	8	0.11	-	0.2	0.22	-	-	-	0.19	-	-	0.33
Clematis terniflora	sweet autumn virginsbower		-	-	-	-	-	-	0.2	-	-	-	-
Clematis virginiana	devil`s darning needles	3	0.11	-	-	-	-	-	-	-	-	-	-
Clitoria mariana	atlantic pigeonwings	7	-	-	-	-	-	0.14	-	-	-	-	-
Cocculus carolinus	carolina coralbead	6	-	-	-	-	-	-	-	-	-	0.2	-
Collinsonia canadensis	richweed	9	-	-	0.6	-	-	-	-	-	-	-	-
Comandra richardsiana	bastard toadflax	6	-	0.33	-	0.11	-	-	-	0.03	-	0.2	-
Commelina erecta	whitemouth dayflower	4	0.11	-	-	-	-	-	0.4	-	-	-	-
Conobea multifida	narrowleaf paleseed	4	-	-	-	-	-	-	-	0.06	-	-	0.33
Conoclinium coelestinum	blue mistflower	4	0.11	-	-	-	-	-	0.2	0.03	-	-	-
Conyza canadensis var. canadensis	fleabane	1	0.44	-	-	0.11	-	-	-	0.03	-	-	-
Coreopsis lanceolata	lanceleaf tickseed	7	0.11	-	-	-	-	0.14	-	0.06	-	-	-
Coreopsis palmata	stiff tickseed	6	-	0.33	-	-	-	0.29	-	0.1	0.14	0.2	-
Coreopsis pubescens	star tickseed	5	-	-	0.2	-	-	-	-	-	-	-	-
Coreopsis tripteris	tall tickseed	6	-	-	0.2	-	-	0.43	-	0.06	-	-	-
Cornus alternifolia	alternateleaf dogwood	7	-	-	-	-	-	-	-	-	-	0.2	-
Cornus drummondii	roughleaf dogwood	1	0.11	1	-	0.33	-	-	0.2	0.26	-	-	-
Cornus florida	flowering dogwood	5	0.22	0.67	0.8	0.33	-	1	-	0.55	0.43	0.4	-
Cornus foemina	stiff dogwood	6	-	-	-	-	-	0.14	-	-	-	-	-
Cornus obliqua	silky dogwood	5	-	-	0.2	-	-	-	-	-	-	-	-
Corylus americana	american hazelnut	2	0.11	-	0.8	-	-	0.71	-	0.06	0.43	0.4	-
Crataegus collina	dotted hawthorn	4	-	-	-	-	-	0.14	-	-	-	-	-
Crataegus crus-galli	cockspur hawthorn	3	-	-	-	-	-	0.29	-	0.06	-	-	-
Crataegus engelmannii	engelmann`s hawthorn	4	-	-	-	-	-	-	-	0.03	-	-	-
Crataegus pruinosa	waxyfruit hawthorn	3	-	-	0.2	-	-	1	-	-	0.29	-	-
Crataegus viridis	green hawthorn	5	-	-	0.2	-	-	0.29	-	-	0.29	-	-
Croton monanthogynus	prairie tea	2	-	0.33	-	-	-	-	0.4	0.1	-	-	0.67
Cryptotaenia canadensis	canadian honewort	2	0.11	-	-	-	-	-	-	0.03	-	-	-
Cunila origanoides	common dittany	5	0.11	0.33	0.2	-	-	0.57	-	0.29	0.29	-	-
Cynanchum laeve	honeyvine	1	-	-	-	-	-	-	0.2	-	-	-	-
Cynoglossum virginianum	wild comfrey	6	0.11	-	-	0.11	-	-	-	0.23	0.14	-	-
Cyperus compressus	poorland flatsedge	4	-	-	-	0.11	-	-	-	-	-	-	-
Cyperus strigosus	strawcolored flatsedge	1	-	-	-	-	-	-	-	-	-	0.2	-
Cystopteris fragilis	brittle bladderfern	5	-	-	-	-	-	-	-	-	-	0.2	-
Cystopteris tennesseensis	tennessee bladderfern	6	0.11	-	-	-	-	-	-	-	-	-	-
Dactylis glomerata	orchardgrass		0.44	-	-	-	-	-	-	-	-	-	-
Dalea candida	white prairie clover	8	-	-	-	-	-	-	-	0.03	-	-	-

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Dalea purpurea	violet prairie clover	8	0.11	-	-	-	-	-	-	-	-	-	-
Danthonia spicata	poverty oatgrass	3	0.22	-	0.4	0.22	-	1	-	0.42	0.29	0.2	-
Daucus carota	queen anne`s lace		0.33	-	-	0.11	-	-	-	0.19	-	-	0.67
Dentaria laciniata	cutleaf toothwort	4	-	-	-	-	-	-	-	0.06	-	-	-
Desmanthus illinoensis	prairie bundleflower	3	0.11	0.33	-	0.11	-	-	-	-	-	-	0.67
Desmodium canescens	hoary ticktrefoil	3	0.11	-	-	-	-	-	-	-	-	-	-
Desmodium cuspidatum	largebract ticktrefoil	4	-	-	0.2	0.22	-	0.29	-	0.19	0.14	-	-
Desmodium dillenii	dillenius` ticktrefoil	3	0.56	0.67	0.6	0.22	-	0.86	-	0.42	0.29	0.2	-
Desmodium glutinosum	pointedleaf ticktrefoil	3	0.11	-	0.8	0.11	-	0.43	-	0.32	0.14	0.4	-
Desmodium laevigatum	smooth ticktrefoil	7	-	0.33	-	-	-	0.43	-	0.13	0.43	-	-
Desmodium marilandicum	smooth small-leaf ticktrefoil	5	-	-	-	-	-	0.14	-	0.06	-	-	-
Desmodium nudiflorum	nakedflower ticktrefoil	4	0.11	-	0.6	0.11	-	1	-	0.39	0.43	0.4	-
Desmodium nuttallii	nuttall`s ticktrefoil	7	-	-	-	-	-	0.29	-	-	0.43	-	-
Desmodium paniculatum	panicledleaf ticktrefoil	3	0.33	0.67	0.2	0.11	-	-	-	0.32	-	-	-
Desmodium pauciflorum	fewflower ticktrefoil	8	-	-	-	-	-	-	-	0.03	-	-	-
Desmodium rotundifolium	prostrate ticktrefoil	6	-	0.33	0.4	-	-	0.71	-	0.32	0.43	0.2	-
Dianthus armeria	deptford pink		0.22	-	-	0.11	-	-	-	0.03	-	-	0.33
Diarrhena americana	american beakgrain	6	0.22	-	-	-	-	-	-	-	-	-	-
Dichanthelium acuminatum	tapered rosette grass	2	-	-	-	-	-	-	-	0.13	0.29	-	-
Diodia teres	poorjoe	2	-	-	-	0.11	-	-	0.4	0.19	-	-	1
Diodia virginiana	virginia buttonweed	5	-	-	-	-	-	-	-	-	0.14	-	-
Dioscorea oppositifolia	chinese yam		-	-	-	-	-	-	0.4	-	-	-	-
Dioscorea quaternata	fourleaf yam	6	0.22	0.33	1	0.11	-	-	0.4	0.32	-	0.2	0.33
Diospyros virginiana	common persimmon	3	0.22	1	1	0.56	0.33	0.57	0.2	0.55	0.43	0.2	-
Dirca palustris	eastern leatherwood	6	-	-	0.2	-	-	-	-	-	-	-	-
Dodecatheon meadia	pride of ohio	5	0.11	-	-	-	-	-	-	-	-	-	-
Echinacea pallida	pale purple coneflower	7	-	-	-	-	-	-	-	0.03	-	-	-
Elaeagnus umbellata	autumn olive		-	0.33	-	-	-	-	0.2	0.16	-	-	-
Eleocharis compressa	flatstem spikerush	6	-	-	-	-	-	-	-	0.03	-	-	-
Elephantopus carolinianus	carolina elephantsfoot	3	0.11	-	0.2	-	-	-	0.2	0.06	-	-	-
Elymus hystrix	eastern bottlebrush grass	4	-	-	0.2	-	-	-	-	0.06	-	-	-
Elymus repens	quackgrass		0.22	-	-	-	-	-	-	-	-	-	-
Elymus virginicus	virginia wildrye	4	0.44	0.33	0.4	0.22	-	0.14	0.2	0.23	-	-	-
Equisetum arvense	field horsetail	1	-	-	-	-	-	-	-	0.06	-	-	-
Equisetum hyemale	scouringrush horsetail	3	-	-	-	0.22	-	-	0.4	0.26	-	-	-
Eragrostis trichodes	sand lovegrass	4	-	-	-	0.22	-	-	-	-	-	-	-
Erechtites hieraciifolia	american burnweed	2	-	-	-	-	-	-	-	-	-	0.2	-
Erigeron annuus	eastern daisy fleabane	1	0.11	-	-	-	-	0.14	-	0.06	-	-	-
Erigeron strigosus	prairie fleabane	3	0.11	-	-	-	-	-	-	0.13	-	-	-
Erucastrum gallicum	common dogmustard		-	-	-	0.11	0.33	-	-	0.1	-	-	-

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Euonymus alatus	burning bush		-	-	-	-	-	-	0.2	-	-	-	-
Euonymus atropurpurea	eastern wahoo	5	0.33	-	0.4	0.33	-	-	0.2	0.06	-	-	-
Euonymus obovata	running strawberry bush	10	-	-	-	0.11	-	-	0.2	-	-	-	-
Eupatorium altissimum	tall thoroughwort	3	0.22	0.33	-	-	-	-	0.4	0.26	-	-	0.33
Eupatorium perfoliatum	common boneset	5	-	-	-	-	-	-	0.2	0.13	-	-	-
Eupatorium purpureum	sweetscented joepyeweed	4	-	-	0.4	-	-	-	-	-	-	-	-
Eupatorium rugosum	white snakeroot	2	0.33	-	0.4	-	-	0.14	0.4	0.16	-	-	-
Eupatorium serotinum	lateflowering thoroughwort	1	0.22	-	-	-	-	-	-	0.03	-	0.2	-
Euphorbia commutata	tinted woodland spurge	5	0.22	-	0.2	0.11	-	-	0.2	0.03	-	0.2	-
Euphorbia corollata	flowering spurge	3	0.11	0.67	0.2	-	-	0.71	0.2	0.23	0.43	0.2	-
Euphorbia dentata	toothed spurge	0	-	-	-	-	-	-	0.2	-	-	-	0.33
Euphorbia maculata	spotted sandmat	0	-	-	-	-	-	-	-	-	-	-	0.67
Euphorbia supina	spotted sandmat	0	-	-	-	-	-	-	-	-	-	-	0.33
Festuca arundinacea	tall fescue		0.56	-	-	0.22	-	-	-	0.26	-	-	0.33
Festuca obtusa	nodding fescue	4	0.11	-	-	-	-	0.14	-	0.03	-	-	-
Fimbristylis puberula	hairy fimbry	7	-	0.33	-	-	-	-	-	-	-	-	-
Fragaria virginiana	virginia strawberry	2	-	-	0.2	0.22	-	-	-	0.13	-	-	-
Fraxinus americana	white ash	3	0.22	1	0.6	0.33	-	-	0.4	0.55	-	0.4	0.33
Fraxinus pennsylvanica	green ash	5	0.22	-	-	-	-	-	-	-	-	-	-
Fraxinus quadrangulata	blue ash	4	-	-	0.2	-	-	-	-	-	-	-	-
Froelichia gracilis	slender snakecotton	3	-	-	-	0.11	-	-	-	-	-	-	-
Galactia volubilis	downy milkpea	6	-	-	-	-	-	0.29	-	0.1	-	-	-
Galium arkansanum	arkansas bedstraw	6	-	-	-	-	-	-	-	0.03	-	-	-
Galium circaezans	licorice bedstraw	4	0.22	1	0.8	0.22	-	0.57	-	0.42	0.29	0.4	-
Galium concinnum	shining bedstraw	4	0.11	-	0.6	0.11	-	0.29	-	0.23	-	0.2	-
Galium pilosum	hairy bedstraw	6	-	0.67	-	0.11	-	0.71	-	0.19	0.29	-	-
Galium triflorum	fragrant bedstraw	4	0.11	-	-	-	-	-	0.2	0.03	-	-	-
Geranium carolinianum	carolina geranium	0	0.11	-	-	-	-	-	-	-	-	-	-
Geranium maculatum	spotted geranium	5	-	-	0.2	-	-	0.29	-	0.03	-	0.2	-
Gerardia flava	smooth yellow false foxglove	8	0.11	0.33	-	-	-	0.14	-	0.13	0.14	0.2	-
Geum canadense	white avens	2	0.11	-	0.4	0.11	-	0.14	-	0.13	0.29	-	-
Gillenia stipulata	indian physic	5	-	0.33	0.2	-	-	0.57	-	0.1	0.14	-	-
Glechoma hederacea	ground ivy		0.11	-	-	-	-	-	-	-	-	-	-
Gleditsia triacanthos	honeylocust	2	0.11	-	0.2	-	-	-	0.4	0.1	-	-	-
Grindelia lanceolata	narrowleaf gumweed	3	-	-	-	-	-	-	-	0.03	-	-	0.67
Hamamelis vernalis	ozark witchhazel	7	-	-	0.2	-	-	0.29	-	-	-	0.2	-
Helianthus annuus	common sunflower	0	-	-	-	-	-	-	-	0.06	-	-	-
Helianthus strumosus	paleleaf woodland sunflower	4	0.22	0.33	0.6	0.33	-	0.57	-	0.42	0.29	-	-
Helianthus tuberosus	jerusalem artichoke	3	0.11	-	-	-	-	-	-	-	-	-	-
Heliopsis helianthoides	smooth oxeye	5	0.11	0.33	0.4	-	-	-	-	0.16	0.14	0.2	-
Heliotropium tenellum	pasture heliotrope	6	-	0.33	-	-	-	-	-	-	-	-	-

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Hepatica nobilis var. acuminata	liverleaf	7	-	-	-	-	-	-	-	-	-	0.2	-
Heuchera americana	american alumroot	7	0.11	-	-	-	-	0.43	-	0.03	-	-	-
Hibiscus syriacus	rose of sharon		-	-	-	-	-	-	0.2	-	-	-	-
Hieracium gronovii	queendevil	4	-	-	0.2	-	-	0.43	-	-	-	-	-
Houstonia longifolia	longleaf summer bluet	5	-	-	-	-	-	-	0.4	0.1	-	-	-
Houstonia nigricans	diamondflowers	5	0.11	0.33	0.2	-	-	-	-	0.23	-	-	-
Hybanthus concolor	eastern greenviolet	7	0.11	-	0.8	-	-	-	-	-	-	-	-
Hydrangea arborescens	wild hydrangea	7	0.11	-	0.4	-	-	-	-	0.03	-	0.2	-
Hydrastis canadensis	goldenseal	6	-	-	0.4	-	-	-	-	-	-	-	-
Hydrophyllum virginianum	shawnee salad	4	-	-	-	-	-	-	-	-	-	0.2	-
Hypericum punctatum	spotted st. johnswort	3	-	-	-	0.11	-	-	-	-	-	-	-
Hypericum spathulatum	shrubby st. johnswort	4	-	-	0.2	-	-	0.43	-	-	-	-	-
Ilex decidua	possumhaw	5	-	0.33	-	-	-	-	-	-	-	-	-
Impatiens capensis	jewelweed	3	0.22	-	-	-	-	-	0.4	0.03	-	-	-
Ipomoea pandurata	man of the earth	2	0.22	-	-	-	-	0.14	-	0.06	-	-	1
Isanthus brachiatus	fluxweed	4	-	0.33	-	-	-	-	-	-	-	-	-
Juglans nigra	black walnut	4	0.22	0.67	0.2	0.11	-	-	0.4	0.26	0.14	0.2	0.33
Juncus brachycarpus	whiteroot rush	7	-	-	-	-	-	-	-	0.16	-	-	-
Juncus dudleyi	dudley`s rush	6	0.11	-	-	0.11	-	-	-	-	-	-	-
Juncus tenuis	poverty rush	0	-	-	-	-	-	-	-	0.13	-	-	-
Juniperus virginiana	eastern redcedar	2	0.33	1	0.4	0.44	0.33	0.86	0.8	0.87	0.43	0.4	-
Krigia biflora	twoflower dwarfdandelion	5	-	-	0.4	-	-	0.57	-	0.13	0.29	0.2	-
Kuhnia eupatorioides	false boneset	5	0.11	-	-	-	-	-	-	0.03	-	-	-
Lactuca canadensis	canada lettuce	2	0.11	-	-	-	-	0.14	-	0.06	0.14	-	-
Lactuca floridana	woodland lettuce	3	0.11	-	0.2	-	-	-	-	0.03	0.14	-	-
Lactuca serriola	prickly lettuce		0.33	-	-	-	-	-	-	-	-	-	0.67
Laportea canadensis	canadian woodnettle	4	0.22	-	-	-	-	-	0.2	-	-	-	-
Lechea villosa	hairy pinweed	5	0.11	-	-	-	-	-	-	-	-	-	-
Leersia virginica	whitegrass	4	-	-	-	-	-	-	-	0.03	-	-	-
Lepidium virginicum	virginia pepperweed	0	0.22	0.33	-	0.22	-	-	-	0.19	-	-	0.67
Lespedeza cuneata	chinese lespedeza		-	-	0.2	-	-	-	-	-	-	0.2	-
Lespedeza hirta	hairy lespedeza	7	-	-	-	-	-	-	-	0.1	0.14	0.2	-
Lespedeza intermedia	violet lespedeza	6	-	-	0.2	0.22	-	0.57	-	0.29	0.14	0.2	-
Lespedeza procumbens	trailing lespedeza	4	-	0.33	-	-	-	0.43	-	0.23	0.14	-	-
Lespedeza repens	creeping lespedeza	4	-	-	-	-	-	0.43	-	0.1	0.14	0.2	-
Lespedeza stipulacea	korean clover		0.11	-	-	-	-	-	-	-	-	-	-
Lespedeza violacea	violet lespedeza	4	-	0.33	0.2	0.11	-	0.71	-	0.19	0.43	-	-
Lespedeza virginica	slender lespedeza	5	-	0.33	-	-	-	-	-	0.23	0.14	-	-
Liatris aspera	tall blazing star	6	-	0.33	-	-	-	0.14	-	0.1	-	-	-
Liatris pycnostachya	prairie blazing star	6	-	-	-	-	-	0.14	-	-	-	-	-
Ligusticum canadense	canadian licorice-root	8	-	-	0.6	-	-	0.29	-	-	0.14	-	-

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Ligustrum obtusifolium	border privet		-	-	-	-	-	-	0.2	-	-	-	-
Lindera benzoin	northern spicebush	5	0.22	-	0.4	-	-	-	-	0.06	-	0.2	-
Linum medium	stiff yellow flax	5	-	-	-	-	-	-	-	0.19	-	-	-
Lithospermum canescens	hoary puccoon	6	0.11	0.33	-	0.11	-	0.14	-	-	-	-	-
Lobelia inflata	indian-tobacco	3	-	-	-	-	-	-	-	0.06	-	-	-
Lobelia spicata	palespike lobelia	5	0.11	0.33	-	-	-	-	-	0.26	-	-	-
Lonicera flava	yellow honeysuckle	5	-	0.67	-	0.11	-	0.43	-	-	0.14	0.2	-
Lonicera japonica	japanese honeysuckle		-	0.33	-	0.11	-	-	0.4	0.03	-	-	0.33
Lonicera maackii	amur honeysuckle		0.22	-	-	0.11	-	-	0.4	0.03	-	-	-
Lotus corniculatus	birdfoot deervetch		-	-	-	0.11	-	-	-	0.13	-	-	-
Luzula bulbosa	bulbous woodrush	4	-	-	-	-	-	-	-	0.06	-	-	-
Lycopus americanus	american water horehound	4	0.22	-	-	-	-	-	-	0.03	-	-	-
Lysimachia ciliata	fringed loosestrife	5	0.11	-	-	-	-	-	-	-	-	-	-
Lysimachia lanceolata	lanceleaf loosestrife	4	0.11	-	0.2	-	-	0.57	-	0.06	0.29	-	-
Lysimachia nummularia	creeping jenny		0.22	-	-	-	-	-	-	-	-	-	-
Maclura pomifera	osage orange		-	-	-	-	-	-	0.2	-	-	-	-
Matelea decipiens	oldfield milkvine	5	0.11	-	0.4	-	-	-	-	0.03	-	-	-
Medicago sativa	alfalfa		-	-	-	0.11	-	-	-	-	-	-	-
Melilotus officinalis	yellow sweetclover		0.11	-	-	0.44	0.33	-	0.2	0.23	-	-	1
Menispermum canadense	common moonseed	4	0.22	-	0.4	-	-	-	0.2	0.03	-	-	-
Monarda bradburiana	eastern beebalm	5	0.22	0.67	1	0.33	-	0.86	-	0.45	0.43	0.2	-
Monarda fistulosa	wild bergamot	4	-	0.33	-	-	-	-	-	-	-	-	-
Morus rubra	red mulberry	4	0.22	-	0.2	0.33	-	0.14	0.2	0.16	-	0.4	-
Muhlenbergia frondosa	wirestem muhly	3	-	-	0.2	-	-	-	-	-	-	-	-
Muhlenbergia sobolifera	rock muhly	4	0.22	0.33	0.6	0.22	-	0.29	-	0.39	-	-	-
Muhlenbergia sylvatica	woodland muhly	5	-	-	-	-	-	-	0.2	-	-	-	-
Nyssa sylvatica	blackgum	5	-	-	0.4	-	-	1	-	0.13	0.43	0.2	-
Oenothera biennis	common evening-primrose	0	0.33	-	0.2	0.11	-	-	0.2	0.06	-	0.2	1
Oenothera laciniata	cutleaf evening-primrose	1	-	-	-	0.11	-	-	-	-	-	-	-
Oenothera macrocarpa	bigfruit evening-primrose	7	-	-	-	0.11	-	-	-	0.06	-	-	-
Opuntia humifusa	devil`s-tongue	4	-	-	-	0.11	-	-	-	0.06	-	-	-
Ostrya virginiana	hophornbeam	4	0.22	-	1	-	-	-	0.4	0.03	-	0.2	-
Oxalis dillenii	common yellow oxalis	0	0.22	-	0.2	-	-	0.14	0.2	0.13	-	-	-
Oxalis violacea	violet woodsorrel	5	-	-	-	-	-	-	-	0.1	-	-	-
Oxypolis rigidior	stiff cowbane	7	-	-	0.2	-	-	-	-	0.03	-	-	-
Panax quinquefolius	american ginseng	8	-	-	-	-	-	-	-	-	-	0.2	-
Panicum acuminatum	tapered rosette grass	2	-	-	-	-	-	0.14	-	0.06	-	0.2	-
Panicum anceps	beaked panicgrass	2	-	-	0.2	0.11	-	-	-	0.13	-	-	0.33
Panicum boscii	bosc`s panicgrass	5	0.22	0.33	0.8	0.33	-	0.71	-	0.42	0.43	-	-
Panicum clandestinum	deertongue	4	-	-	0.2	-	-	-	0.2	-	-	-	-
Panicum commutatum	variable panicgrass	7	-	0.33	0.2	-	-	0.71	-	0.06	0.43	0.2	-
Panicum dichotomum	cypress panicgrass	6	0.11	0.33	0.4	-	-	0.71	-	0.23	0.43	0.2	-

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Panicum laxiflorum	openflower rosette grass	6	-	0.33	-	0.22	-	0.29	-	-	-	-	-
Panicum linearifolium	slimleaf panicgrass	5	0.11	0.33	0.6	0.11	-	0.29	-	0.32	-	-	-
Panicum oligosanthes	heller`s rosette grass	6	-	-	-	-	-	-	-	0.03	-	-	-
Panicum sphaerocarpon	roundseed panicgrass	5	-	-	-	-	-	0.29	-	-	-	-	-
Panicum virgatum	switchgrass	4	0.11	0.33	-	0.56	0.33	-	-	0.45	-	-	1.33
Parietaria pensylvanica	pennsylvania pellitory	3	0.11	-	-	-	-	-	-	-	-	-	-
Parthenium integrifolium	wild quinine	6	-	-	-	-	-	0.57	-	0.19	0.43	0.2	-
Parthenocissus quinquefolia	virginia creeper	3	0.44	1	1	0.33	-	1	0.8	0.48	0.43	0.4	-
Passiflora lutea	yellow passionflower	4	0.22	0.67	0.4	0.11	-	0.29	0.2	0.13	0.14	-	-
Pedicularis canadensis	canadian lousewort	5	0.11	-	-	-	-	0.14	-	0.06	-	-	-
Pellaea atropurpurea	purple cliffbrake	7	0.11	-	-	0.11	-	-	-	-	-	-	-
Penstemon pallidus	pale beardtongue	4	-	0.67	-	0.11	-	-	-	0.06	-	-	-
Perilla frutescens	beefsteakplant		0.11	-	-	-	-	-	-	-	-	-	-
Phleum pratense	timothy		0.11	-	-	0.11	-	-	-	0.03	-	-	-
Phlox divaricata	wild blue phlox	4	0.22	-	-	-	-	-	0.2	0.03	-	-	-
Phlox paniculata	fall phlox	3	0.22	-	-	-	-	-	0.2	-	-	-	-
Phlox pilosa	downy phlox	6	-	-	-	-	-	0.14	-	0.1	-	-	-
Phragmites australis	common reed		-	-	-	-	-	-	-	0.03	-	-	-
Phryma leptostachya	american lopseed	2	-	-	0.4	0.11	-	0.14	0.4	0.13	0.14	0.2	-
Physalis heterophylla	clammy groundcherry	3	-	-	-	-	-	-	-	-	-	-	0.33
Physalis virginiana	virginia groundcherry	3	0.22	-	-	-	-	0.29	-	0.13	-	-	-
Physocarpus opulifolius	common ninebark	5	-	-	0.2	-	-	-	-	-	-	-	-
Physostegia virginiana	obedient plant	5	-	-	0.2	-	-	0.14	-	0.03	-	-	-
Phytolacca americana	american pokeweed	2	-	-	-	-	-	-	-	-	0.14	-	-
Pilea pumila	canadian clearweed	4	0.11	-	-	-	-	-	0.4	-	-	-	-
Pinus echinata	shortleaf pine	5	-	-	-	-	-	0.71	-	-	0.29	0.2	-
Plantago lanceolata	narrowleaf plantain		0.11	-	-	-	-	-	-	-	-	-	0.67
Platanus occidentalis	american sycamore	3	0.44	-	0.2	-	0.33	-	0.8	0.1	-	0.2	-
Poa annua	annual bluegrass		-	-	-	-	-	-	-	0.03	-	-	0.33
Poa chapmaniana	chapman`s bluegrass	2	0.56	-	-	-	-	-	-	0.06	-	-	-
Poa compressa	canada bluegrass		0.11	-	-	-	-	0.14	-	-	-	-	-
Poa sylvestris	woodland bluegrass	5	0.11	-	-	-	-	-	-	0.13	-	-	-
Podophyllum peltatum	mayapple	4	0.11	-	-	0.11	-	-	-	0.06	-	-	-
Polanisia dodecandra	redwhisker clammyweed	1	-	-	-	0.44	0.33	-	-	0.19	-	-	0.33
Polygala senega	seneca snakeroot	6	-	-	0.2	-	-	-	-	-	-	-	-
Polygala verticillata	whorled milkwort	4	-	0.33	-	-	-	-	-	-	-	-	-
Polygonatum commutatum	smooth solomon`s seal	4	0.22	-	-	0.11	-	-	-	0.06	-	-	-
Polygonum coccineum	longroot smartweed	5	0.11	-	-	-	-	-	-	-	-	-	0.33
Polygonum convolvulus	black bindweed		-	-	-	-	-	-	-	0.03	-	-	-
Polygonum hydropiperoides	swamp smartweed	4	0.22	-	-	-	-	-	0.2	-	-	-	-

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Polygonum lapathifolium	curlytop knotweed	0	-	-	-	0.11	-	-	-	-	-	-	-
Polygonum scandens	climbing false buckwheat	3	0.11	-	-	-	-	-	-	0.03	-	-	-
Polygonum virginianum	jumpseed	1	0.11	-	-	-	-	-	-	-	-	-	-
Polymnia uvedalia	hairy leafcup	8	-	-	-	-	-	-	-	-	-	0.2	-
Polystichum acrostichoides	christmas fern	5	-	-	-	-	-	0.29	-	0.06	-	-	-
Populus deltoides	eastern cottonwood	2	0.33	-	-	0.11	-	-	0.2	-	-	-	-
Potentilla recta	sulphur cinquefoil		0.11	-	-	-	-	-	-	-	0.14	-	-
Potentilla simplex	common cinquefoil	3	-	-	0.2	-	-	0.86	-	0.1	0.29	-	-
Prenanthes altissima	tall rattlesnakeroot	5	-	-	0.2	0.11	-	0.71	0.2	0.06	0.14	0.2	-
Prunella vulgaris	common selfheal		-	-	-	-	-	0.14	-	0.03	-	-	-
Prunus americana	american plum	4	0.22	-	0.2	-	-	0.29	-	0.1	0.14	-	-
Prunus hortulana	hortulan plum	3	0.22	-	-	-	-	-	-	-	-	-	-
Prunus mahaleb	mahaleb cherry		-	-	-	-	-	-	0.2	-	-	-	-
Prunus mexicana	mexican plum	3	-	-	-	0.11	-	-	-	-	-	-	-
Prunus serotina	black cherry	2	0.11	-	0.8	0.33	-	1	0.2	0.16	0.43	0.2	-
Psoralea psoralioides	sampson`s snakeroot	7	-	-	-	-	-	0.14	-	-	-	-	-
Ptelea trifoliata	common hoptree	5	0.11	0.33	-	-	-	-	0.6	0.03	-	-	-
Pteridium aquilinum	western brackenfern	4	-	-	0.2	-	-	0.43	-	-	0.14	0.2	-
Pycnanthemum albescens	whiteleaf mountainmint	7	0.11	-	-	-	-	-	-	-	-	-	-
Pycnanthemum tenuifolium	narrowleaf mountainmint	4	0.11	-	-	0.22	-	-	-	0.13	-	-	-
Quercus alba	white oak	4	0.11	0.33	0.8	0.11	-	1	-	0.45	0.43	0.4	-
Quercus coccinea	scarlet oak	5	0.11	-	0.2	-	-	0.86	0.2	0.23	-	0.2	-
Quercus imbricaria	shingle oak	3	0.11	0.67	-	0.11	-	0.14	0.2	0.1	-	-	-
Quercus macrocarpa	bur oak	4	0.11	-	-	-	-	-	-	-	-	-	-
Quercus marilandica	blackjack oak	4	-	0.33	-	-	-	-	-	0.1	-	-	-
Quercus muehlenbergii	chinkapin oak	5	0.22	1	0.6	0.33	-	-	0.6	0.19	-	0.4	-
Quercus rubra	northern red oak	5	0.11	0.67	0.8	0.44	-	0.29	0.2	0.29	0.43	0.2	0.33
Quercus stellata	post oak	4	0.11	1	0.2	0.44	-	0.57	-	0.32	0.29	-	-
Quercus velutina	black oak	4	0.11	0.33	0.4	0.33	-	1	-	0.58	0.43	0.2	-
Ranunculus abortivus	littleleaf buttercup	0	0.11	-	-	-	-	-	-	-	-	-	-
Ranunculus harveyi	harvey`s buttercup	7	0.11	-	-	-	-	-	-	0.03	-	-	-
Ranunculus hispidus	bristly buttercup	6	0.11	-	-	-	-	0.14	-	0.13	-	-	-
Ratibida pinnata	pinnate prairie coneflower	5	-	-	0.2	-	-	-	-	0.03	-	-	-
Rhamnus caroliniana	carolina buckthorn	6	0.22	0.67	0.8	0.33	-	0.71	0.2	0.48	0.29	0.4	-
Rhus aromatica	fragrant sumac	3	0.22	1	0.4	0.44	-	0.57	0.2	0.71	0.43	0.2	-
Rhus copallinum	flameleaf sumac	2	-	0.33	-	0.33	-	0.71	0.4	0.23	0.57	0.2	-
Rhus glabra	smooth sumac	1	-	-	-	-	-	-	0.2	-	-	-	-
Ribes missouriense	missouri gooseberry	3	-	0.33	0.2	-	-	0.14	0.2	0.03	-	0.2	-
Robinia pseudoacacia	black locust	2	0.11	-	-	0.11	-	-	-	-	-	-	-
Rosa carolina	carolina rose	4	0.22	0.33	0.4	0.33	-	0.86	-	0.32	0.43	-	-
Rosa multiflora	multiflora rose		0.11	-	-	-	-	0.14	-	0.1	0.14	-	-

Scientific Name	Common Name	C value	Site (number of plots)										
			Desloge (9)	Elvins (3)	Glover (5)	Leadwood (9)	Missouri Mines (3)	Nadist (7)	National (5)	St. Joe (31)	Sweetwater (7)	West Fork (5)	Yoder (3)
Rosa setigera	climbing rose	4	-	0.33	-	-	-	-	-	-	-	-	-
Rubus flagellaris	northern dewberry	2	-	0.33	0.4	-	-	1	-	0.19	0.43	0.2	-
Rubus pensilvanicus	pennsylvania blackberry	2	-	-	-	-	-	0.29	-	0.13	0.29	0.2	-
Rudbeckia fulgida	orange coneflower	7	-	-	-	0.11	-	-	-	-	-	-	0.67
Rudbeckia hirta	blackeyed susan	1	0.11	-	-	-	-	-	-	0.35	0.14	-	-
Rudbeckia laciniata	cutleaf coneflower	3	0.22	-	0.2	-	-	-	-	-	-	-	-
Rudbeckia missouriensis	missouri orange coneflower	6	-	0.33	0.2	-	-	-	-	-	-	-	-
Rudbeckia triloba	browneyed susan	4	-	-	0.2	-	-	-	0.2	-	-	-	-
Ruellia humilis	fringeleaf wild petunia	3	0.11	0.33	-	-	-	-	-	-	-	-	-
Ruellia pedunculata	stalked wild petunia	5	0.22	0.33	0.4	0.11	-	0.14	-	0.32	-	-	-
Ruellia strepens	limestone wild petunia	3	0.11	-	-	-	-	-	0.4	-	-	-	-
Rumex crispus	curly dock		0.56	-	-	-	-	-	-	-	-	-	-
Sabatia angularis	rosepink	4	-	0.33	-	0.11	-	-	-	0.16	-	-	-
Salix caroliniana	coastal plain willow	4	0.11	-	-	0.11	-	0.14	-	-	-	0.2	-
Salix interior	sandbar willow	3	0.22	-	-	-	-	-	-	0.1	-	0.2	-
Salsola tragus	prickly russian thistle		-	-	-	0.33	1	-	0.6	0.16	-	-	-
Salvia lyrata	lyreleaf sage	4	0.22	-	0.4	-	-	-	-	0.06	-	-	-
Sambucus canadensis	common elderberry	2	0.33	-	-	-	-	-	0.4	-	-	0.2	-
Sanguinaria canadensis	bloodroot	5	0.11	-	0.2	-	-	-	-	0.03	-	0.2	-
Sanicula canadensis	canadian blacksnakeroot	3	0.11	0.67	0.6	0.22	-	0.14	-	0.23	0.29	0.4	-
Sanicula gregaria	clustered blacksnakeroot	2	0.22	-	0.2	-	-	-	0.2	0.06	-	-	-
Sassafras albidum	sassafras	2	0.22	0.33	0.8	0.11	-	1	0.2	0.42	0.43	0.4	-
Satureja arkansana	limestone calamint	7	0.11	-	-	-	-	-	-	-	-	-	-
Schizachyrium scoparium	little bluestem	5	0.22	0.67	-	0.44	0.67	0.57	0.6	0.65	0.43	0.4	-
Scirpus pendulus	rufous bulrush	4	-	-	-	-	-	-	-	0.13	-	-	-
Scrophularia marilandica	carpenter`s square	3	0.22	-	-	-	-	-	0.2	-	-	-	-
Scutellaria incana	hoary skullcap	5	0.22	-	0.6	0.11	-	0.29	-	0.16	-	-	-
Scutellaria ovata	heartleaf skullcap	5	-	-	-	-	-	-	-	-	-	0.2	-
Scutellaria parvula	small skullcap	4	0.11	0.33	-	0.11	-	-	-	-	-	-	-
Senecio aureus	golden ragwort	5	-	-	0.2	-	-	-	-	-	-	-	-
Senecio obovatus	roundleaf ragwort	4	-	-	0.2	0.11	-	-	-	-	-	-	-
Senecio plattensis	prairie groundsel	6	-	-	-	-	-	-	-	0.03	-	-	-
Setaria viridis	green bristlegrass		-	-	-	0.22	-	-	-	0.06	-	0.2	1
Sicyos angulatus	oneseed burr cucumber	4	0.22	-	-	-	-	-	-	-	-	-	-
Sideroxylon lanuginosum ssp oblongifolium	rusty blackhaw	5	0.22	1	0.8	0.33	-	-	0.2	0.39	-	0.2	-
Silene antirrhina	sleepy silene	2	-	-	-	0.11	-	-	-	0.06	-	-	-
Silene csereii	balkan catchfly		0.33	-	-	0.33	1	-	0.6	0.19	-	-	1
Silene stellata	widowsfrill	5	-	-	0.2	-	-	0.14	-	0.1	-	-	-
Silene virginica	fire pink	7	0.11	-	-	-	-	-	-	0.03	-	0.2	-
Silphium asteriscus	starry rosinweed	8	0.22	-	0.4	-	-	0.71	-	-	0.43	0.2	-

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Silphium integrifolium	wholeleaf rosinweed	4	0.11	0.33	0.4	-	-	0.14	-	-	-	-	0.33
Silphium perfoliatum	cup plant	3	0.11	-	0.2	-	-	-	0.2	-	-	-	-
Silphium terebinthinaceum	prairie rosinweed	5	-	0.33	-	-	-	-	-	-	-	-	-
Sisyrinchium campestre	prairie blue-eyed grass	4	-	-	-	-	-	-	-	0.03	-	-	-
Smilacina racemosa	feathery false lily of the vally	4	0.22	-	0.6	0.11	-	0.86	-	0.06	0.43	0.4	-
Smilax bona-nox	saw greenbrier	3	-	-	0.8	-	-	-	-	0.06	0.14	-	-
Smilax ecirrata	upright carrionflower	5	0.11	0.33	-	-	-	0.14	-	-	-	-	-
Smilax herbacea	smooth carrionflower	5	0.11	-	-	0.11	-	-	-	-	-	-	-
Smilax pulverulenta	downy carrionflower	6	-	-	0.4	-	-	0.71	-	0.06	0.29	-	-
Smilax tamnoides	bristly greenbrier	3	0.44	1	0.8	0.33	-	0.57	0.4	0.42	0.43	0.2	0.33
Solanum carolinense	carolina horsenettle	0	0.22	-	-	-	-	-	-	-	-	-	0.33
Solidago altissima	canada goldenrod	1	0.44	-	-	0.11	-	-	-	0.16	-	-	0.33
Solidago arguta	atlantic goldenrod	6	-	-	0.6	-	-	1	-	-	0.43	0.2	-
Solidago buckleyi	buckley`s goldenrod	9	0.11	0.33	0.6	-	-	0.57	-	0.16	0.43	-	-
Solidago caesia	wreath goldenrod	7	0.11	-	-	-	-	-	-	-	-	-	-
Solidago flexicaulis	zigzag goldenrod	6	-	-	-	-	-	-	-	-	-	0.2	-
Solidago gigantea	giant goldenrod	4	0.44	-	-	-	-	-	0.2	-	-	0.2	-
Solidago hispida	hairy goldenrod	6	-	-	0.2	-	-	0.29	-	0.03	0.29	0.2	-
Solidago nemoralis	gray goldenrod	2	0.11	0.33	-	0.22	-	0.29	0.4	0.29	-	0.4	-
Solidago radula	western rough goldenrod	6	-	0.33	-	-	-	0.14	-	0.1	0.14	0.2	-
Solidago ulmifolia	elmleaf goldenrod	4	0.22	1	0.8	0.33	-	0.43	-	0.42	0.14	0.2	-
Sonchus asper	spiny sowthistle		-	-	-	-	-	-	-	-	-	-	0.33
Sorghastrum nutans	indiangrass	5	0.11	-	-	-	-	-	-	0.03	-	-	-
Sorghum halepense	johnsongrass		-	-	-	-	-	-	-	-	-	-	0.33
Specularia perfoliata	clasping venus` looking-glass	2	-	-	-	-	-	-	-	0.06	-	-	-
Sphenopholis nitida	shiny wedgescale	7	-	-	-	-	-	0.14	-	0.29	-	-	-
Spigelia marilandica	woodland pinkroot	8	-	-	-	-	-	-	-	0.06	-	-	-
Sporobolus cryptandrus	sand dropseed	5	-	-	-	0.33	-	-	-	-	-	-	-
Sporobolus heterolepis	prairie dropseed	6	-	0.33	-	-	-	-	-	0.03	-	-	-
Stachys tenuifolia	smooth hedgenettle	4	0.22	-	-	-	-	-	-	-	-	-	-
Staphylea trifolia	american bladdernut	5	0.11	-	0.2	-	-	-	-	-	-	0.2	-
Strophostyles umbellata	pink fuzzybean	3	-	-	-	-	-	-	-	0.06	-	-	-
Stylosanthes biflora	sidebeak pencilflower	5	-	-	-	-	-	-	-	0.03	-	-	-
Swertia caroliniensis	american columbo	7	0.11	-	-	-	-	-	-	0.03	-	-	-
Symphoricarpos orbiculatus	coralberry	1	0.33	0.33	0.6	0.33	-	0.71	0.4	0.32	0.29	0.2	-
Symphyotrichum anomalum	manyray aster	6	0.22	-	0.2	0.22	-	0.86	-	0.42	0.29	-	-
Symphyotrichum cordifolium	common blue wood aster	7	-	-	0.4	-	-	0.14	-	0.03	-	-	-
Symphyotrichum drummondii	drummond`s aster	4	-	-	-	-	-	-	-	0.1	-	-	-
Symphyotrichum oblongifolium	aromatic aster	6	0.11	-	-	-	-	-	0.6	0.03	-	-	0.67

			Site (number of plots)										
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Symphyotrichum patens	late purple aster	5	0.22	0.33	0.4	-	-	0.57	-	0.29	0.43	0.2	-
Symphyotrichum sagittifolium	common blue wood aster	4	0.11	-	-	-	-	0.14	-	-	-	-	-
Taenidia integerrima	yellow pimpernel	6	-	-	-	-	-	-	-	0.06	-	-	-
Taraxacum officinale	common dandelion		-	-	-	-	-	-	-	-	-	0.2	-
Tephrosia virginiana	virginia tephrosia	5	-	-	-	-	-	-	-	0.1	0.14	0.2	-
Teucrium canadense	canada germander	2	-	-	-	-	-	-	0.2	0.06	-	-	0.33
Thalictrum revolutum	waxyleaf meadow-rue	5	0.22	-	0.2	-	-	-	0.4	-	-	-	-
Thaspium barbinode	hairyjoint meadowparsnip	6	-	-	0.4	-	-	-	-	0.03	-	-	-
Thaspium trifoliatum	purple meadowparsnip	6	-	-	-	-	-	-	-	0.03	-	-	-
Thlaspi arvense	field pennycress		0.11	-	-	-	-	-	-	-	-	-	-
Tilia americana	american basswood	5	-	-	-	-	-	-	-	-	-	0.2	-
Torilis arvensis	spreading hedgeparsley		-	-	-	-	-	-	-	-	-	-	0.33
Toxicodendron radicans	eastern poison ivy	2	0.33	0.33	0.6	0.22	-	0.71	0.4	0.23	0.29	0.4	-
Tragopogon dubius	yellow salsify		-	-	-	-	-	-	-	0.03	-	-	0.33
Tridens flavus	purpletop tridens	1	0.22	0.33	-	0.11	-	-	-	0.29	-	-	0.33
Trifolium campestre	field clover		-	-	-	-	-	-	-	0.1	-	-	0.33
Trifolium dubium	suckling clover		0.11	-	-	-	-	-	-	-	-	-	-
Trifolium reflexum	buffalo clover	10	0.22	-	-	-	-	-	-	-	-	-	-
Triosteum angustifolium	yellowfruit horse-gentian	5	0.22	0.67	0.4	0.33	-	-	-	0.1	-	-	-
Tripsacum dactyloides	eastern gamagrass	5	0.11	-	-	-	-	-	-	-	-	-	-
Triticum aestivum	common wheat		0.44	-	-	-	-	-	-	-	-	-	-
Ulmus alata	winged elm	4	0.22	1	0.2	0.11	-	-	0.4	0.19	0.14	-	-
Ulmus americana	american elm	4	0.44	0.33	0.2	-	-	-	0.4	0.13	0.14	-	0.33
Ulmus pumila	siberian elm		-	-	-	0.11	-	-	0.2	-	-	-	-
Ulmus rubra	slippery elm	3	-	-	0.8	0.33	-	-	0.2	0.35	0.14	0.4	-
Uvularia grandiflora	largeflower bellwort	6	0.11	-	0.6	-	-	-	-	0.1	-	-	-
Vaccinium arboreum	farkleberry	6	-	-	-	-	-	0.14	-	0.06	0.29	-	-
Vaccinium stamineum	deerberry	6	-	-	0.4	-	-	0.86	-	0.13	0.14	0.2	-
Vaccinium vacillans	blue ridge blueberry	5	-	-	0.2	-	-	1	-	0.13	0.29	0.2	-
Veratrum woodii	wood`s bunchflower	8	0.11	-	-	-	-	-	-	-	-	0.2	-
Verbascum blattaria	moth mullein		-	-	-	-	-	-	-	-	-	-	0.33
Verbascum thapsus	common mullein		0.33	-	-	0.11	-	-	-	0.1	-	-	0.33
Verbena canadensis	rose mock vervain	5	-	-	0.2	-	-	-	-	-	-	-	-
Verbena stricta	hoary verbena	3	0.11	-	-	-	-	-	0.2	0.03	-	-	0.33
Verbena urticifolia	white vervain	4	0.11	-	-	-	-	-	0.2	0.06	-	-	-
Verbesina alternifolia	wingstem	4	0.22	-	0.4	-	-	-	0.4	-	-	-	-
Verbesina helianthoides	gravelweed	4	0.11	-	-	0.22	-	0.29	-	0.23	-	-	-
Verbesina virginica	white crownbeard	5	-	-	0.2	-	-	-	0.2	-	-	-	-
Vernonia baldwinii	baldwin`s ironweed	2	0.11	0.67	0.8	0.33	-	0.43	-	0.42	0.29	-	0.33
Vernonia crinita	arkansas ironweed	6	-	-	0.2	-	-	0.14	-	-	-	-	-
Veronica arvensis	corn speedwell		0.22	-	-	-	-	-	-	0.06	-	-	-

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Veronica serpyllifolia	thymeleaf speedwell		0.11	-	-	-	-	-	-	-	-	-	-
Veronicastrum virginicum	culver`s root	7	0.11	-	-	-	-	-	-	0.03	-	-	-
Viburnum molle	softleaf arrowwood	8	-	-	-	-	-	-	-	-	-	0.4	-
Viburnum rufidulum	rusty blackhaw	4	0.22	1	0.8	0.33	-	0.86	0.2	0.23	-	-	-
Vicia caroliniana	carolina vetch	6	-	-	0.2	-	-	0.29	-	0.03	-	-	-
Viola pedata	birdfoot violet	5	-	0.33	-	-	-	-	-	-	-	-	-
Viola pensylvanica	downy yellow violet	5	0.11	-	-	-	-	-	-	-	-	-	-
Viola sororia	common blue violet	2	0.33	-	0.6	0.22	-	-	-	0.1	-	-	-
Viola striata	striped cream violet	3	0.22	-	-	-	-	-	0.2	-	-	-	-
Viola triloba	early blue violet	5	0.11	-	0.4	0.11	-	0.86	-	0.39	0.43	-	-
Vitis aestivalis	summer grape	5	0.33	0.67	0.8	0.22	-	1	0.4	0.45	0.57	0.2	0.33
Vitis rupestris	sand grape	7	-	-	-	-	-	-	-	0.03	-	-	-
Vitis vulpina	frost grape	5	0.22	0.33	0.4	0.11	-	-	0.2	0.29	0.29	0.2	-
Vulpia octoflora	sixweeks fescue	2	0.22	-	-	-	-	-	-	-	-	-	-
Woodsia obtusa	bluntlobe cliff fern	5	-	-	-	-	-	-	-	0.06	-	-	-
Xanthium strumarium	rough cockleburr		0.11	-	-	-	-	-	-	-	-	-	0.67
Yucca smalliana	adam`s needle		0.11	-	-	-	-	-	-	0.06	-	-	-
Zizia aptera	meadow zizia	7	-	-	0.6	-	-	0.29	-	0.03	-	-	-
Zizia aurea	golden zizia	5	0.22	-	-	0.11	-	0.14	-	0.1	-	-	-

Appendix V. FQA plot locations

Coordinates (UTM, NAD83, Zone 15N) have been post-processed against NOAA-CORS data (*http://www.ngs.noaa.gov/CORS/Data.html*)

Plot	Plot type	Easting	Northing	Elev (m)	Comments
desloge01	remediated chat/tailings	715674	4195783	224	
desloge02	contaminated native soil	716053	4195991	196	
desloge03	remediated chat/tailings	715558	4196089	225	
desloge04	remediated chat/tailings	715136	4196674	207	15 - 20 m from main road
desloge05	contaminated native soil	715231	4196496	218	
desloge06	contaminated native soil	715217	4195853	215	
desloge07	remediated chat/tailings	715748	4196517	207	
desloge09	remediated chat/tailings	715269	4195599	210	
desloge10	contaminated native soil	715085	4195688	202	
elvins01	contaminated native soil	717214	4191307	242	
elvins02	contaminated native soil	717189	4191435	250	
elvins03	contaminated native soil	716812	4191939	280	
glover01	smelter contaminated	704631	4151292	252	Toe slope to small terrace with concave drain from se to nw through plot.
glover02	smelter contaminated	704336	4151436	241	
glover03	smelter contaminated	704425	4151486	279	GPS coordinates recorded in field (not post-processed or averaged)
glover04	smelter contaminated	704572	4152090	280	GPS coordinates recorded in field; sides at 320 and 50 degrees from GPS
glover05	smelter contaminated	704535	4150891	288	GPS coordinates recorded in field (not post-processed or averaged)
leadwood01	contaminated native soil	710377	4193309	244	
leadwood02	revegetated chat/tailings	710964	4192327	249	
leadwood03	revegetated chat/tailings	710886	4191874	245	
leadwood04	chat/tailings	711002	4193066	233	
leadwood05	contaminated native soil	711469	4190570	266	
leadwood06	chat/tailings	711093	4191458	247	
leadwood07	revegetated chat/tailings	711306	4190735	256	
leadwood08	chat/tailings	711527	4190630	262	Sides at 75 and 255 degrees from GPS location
leadwood09	contaminated native soil	711568	4190651	267	
momines01	chat/tailings	719293	4190847	246	Sides at 57 and 327 degrees from GPS location
momines02	chat/tailings	719411	4190890	248	Adjacent to largest (third?) thickening pool. 25 x 16 to fit.
momines03	chat/tailings	718987	4190651	242	At se end of boneyard in missouri mine shs
nadist01	reference-bottom	662478	4139080	327	Alluvial fan and braided channel from drain to wsw

Plot	Plot type	Easting	Northing	Elev (m)	Comments
nadist02	reference-summit	662224	4138724	357	
nadist03	reference-bottom	662662	4138964	328	
nadist04	reference-summit	663018	4138779	346	
nadist05	reference-bottom	664563	4139855	325	
nadist06	reference-summit	664962	4140274	349	
nadist07	reference-bottom	664342	4140063	306	Sides at 335 and 65 degrees from GPS
national01	chat/tailings	718954	4193304	200	Sides at 50 and 140 degrees from GPS location; below base of rail bed.
national02	chat/tailings	718949	4193307	202	Sides at 320 and 40 degrees from GPS location point
national03	chat/tailings	719032	4193261	201	Sides 12 x 33 at 210 and 120 degrees, respectively, from GPS location
national04	contaminated native soil	719050	4192868	191	Sides 16 x 25 at 322 and 52 degrees, respectively from GPS location
national05	contaminated native soil	719526	4193553	183	
stjoe01	reference-summit	718056	4185758	310	
stjoe03	reference-bottom	717946	4186372	274	Sides 10 x 40 at 310 and 40 degrees, respectively from GPS location
stjoe04	reference-summit	716518	4188149	282	
stjoe06	reference-summit	722635	4185698	331	N facing shoulder with old road to south 30 m.
stjoe07	reference-bottom	722158	4185225	293	
stjoe08	reference-bottom	722064	4184914	281	
stjoe09	contaminated native soil	720180	4190100	273	ATV trail to sw, dolomitic woods with variable depth soil but no glady patches
stjoe10	contaminated native soil	720057	4189737	276	Small trail to wsw
stjoe11	contaminated native soil	720511	4188814	285	ATV trail to west 2 m at nw corner, possible test hole in plot
stjoe12	chat/tailings	718687	4191029	224	Remnant toe of Federal pile
stjoe13	chat/tailings	718940	4190862	243	
stjoe14	chat/tailings	718819	4190898	231	Near old rail bed
stjoe15	chat/tailings	719768	4189318	278	
stjoe16	revegetated chat/tailings	718849	4189340	262	
stjoe17	revegetated chat/tailings	718553	4189326	260	
stjoe18	revegetated chat/tailings	718464	4189161	260	
stjoe19	revegetated chat/tailings	718829	4188828	262	
stjoe20	revegetated chat/tailings	718553	4189498	259	
stjoe21	chat/tailings	720441	4189314	291	Outside of ATV use area; protected by guardrail
stjoe22	chat/tailings	719818	4190634	268	
stjoe23	chat/tailings	719583	4190823	256	
stjoe24	chat/tailings	719966	4189169	287	Sides 10 x 40 at 350 and 80, respectively, from GPS point
stjoe25	chat/tailings	719052	4189960	258	

Plot	Plot type	Easting	Northing	Elev (m)	Comments
stjoe26	revegetated chat/tailings	718642	4189863	257	
stjoe29	revegetated chat/tailings	718980	4188743	261	
stjoe30	contaminated native soil	719255	4189359	279	Trails north and south but undisturbed by riding; trash in plot
stjoe31	contaminated native soil	719295	4188916	282	Trail to south and west but plot undisturbed by ATV use
stjoe32	contaminated native soil	719704	4189085	282	North facing slope 50 m from tailings
stjoe33	contaminated native soil	719445	4188588	274	Trail to north and se
stjoe34	contaminated native soil	718240	4190317	251	Old unused trail through nw part of plot
stjoe35	contaminated native soil	718123	4190439	254	ATV trails nearby but no evidence of impact in plot
sweetwater01	contaminated native soil	664668	4138306	317	Shoulder-summit
sweetwater02	chat/tailings	664562	4138116	305	Months to years since deposition
sweetwater03	chat/tailings	663657	4137224	332	SE corner about 5 m from edge of tailings
sweetwater04	chat/tailings	663822	4137665	329	N edge 10 m from edge of tailings
sweetwater05	contaminated native soil	663813	4137715	330	Long-abandoned rd through east of plot. old stump present
sweetwater06	chat/tailings	663610	4137403	332	Edge of tailings 15 m to north
sweetwater07	contaminated native soil	663699	4137197	348	GPS coordinates recorded in field (not post-processed or averaged)
westfork01	chat/tailings	667348	4149301	309	
westfork02	chat/tailings	667383	4149153	310	Under power lines, old rd to west, cut bank on south edge
westfork03	chat/tailings	666897	4149484	306	ATV tracks through plot but no perceived vegetation impact
westfork04	contaminated native soil	667376	4150624	298	Sides at 152 and 62 degrees from GPS location
westfork05	contaminated native soil	667340	4150796	293	Earthworks to southeast
yoder01	chat/tailings	715535	4194458	217	Sides 16 x 25 at 70 and 340 degrees, respectively, from GPS location
yoder02	chat/tailings	715459	4194429	212	Sides at 53 and 323 degrees from GPS location
yoder03	chat/tailings	715319	4194403	211	GPS and photo on northeast corner

Appendix VI. Environmental measurements from all plots

				Environmental Variable % Cover					Vegetation % Cover		
Plot	Plot type	slope	aspect	bare substrate	litter	native rock	tree root/bole	woody debris	ground- flora	shrub/ sapling	canopy/ subcanopy
desloge01	remediated mine waste	0	-	55	10	0	0	1	60	1	0
desloge02	contaminated native soil	0	-	75	10	0	4	7	60	35	80
desloge03	remediated mine waste	0	-	2	5	0	0	0	93	0	0
desloge04	remediated mine waste	0	-	15	20	0	0	0	95	0	0
desloge05	contaminated native soil	9	260	9	90	0	2	4	13	35	70
desloge06	contaminated native soil	9	278	2	60	10	2	1	23	45	35
desloge07	remediated mine waste	3	46	0	0	0	0	0	100	1	0
desloge09	remediated mine waste	5	244	1	6	0	0	0	100	0	0
desloge10	contaminated native soil	0	-	38	16	0	3	9	87	38	83
elvins01	contaminated native soil	6	190	19	26	18	1	1	52	28	5
elvins02	contaminated native soil	3	54	1	91	0	4	3	43	38	74
elvins03	contaminated native soil	12	222	2	85	2	3	4	19	55	47
glover01	smelter contaminated	5	333	1	86	4	4	2	22	38	64
glover02	smelter contaminated	0	-	64	20	4	3	5	53	39	57
glover03	smelter contaminated	24	203	6	74	6	5	3	49	42	86
glover04	smelter contaminated	14	135	1	89	7	3	2	29	27	80
glover05	smelter contaminated	26	250	2	90	1	4	6	14	23	60
lw01	contaminated native soil	6	5	1	91	0	5	3	19	21	73
lw02	revegetated mine waste	3	222	8	17	0	0	0	87	0	0
lw03	revegetated mine waste	2	225	30	30	0	1	1	63	21	4
lw04	untreated mine waste	6	35	100	0	0	0	0	1	0	0
lw05	contaminated native soil	5	344	0	87	0	5	2	43	58	84
lw06	untreated mine waste	5	317	95	1	0	0	0	6	0	0
lw07	revegetated mine waste	1	295	53	9	0	1	1	37	2	0

Plot	Plot type	slope	aspect	Environmental Variable % Cover: bare substrate	litter	native rock	tree root/bole	woody debris	Vegetation % Cover: ground- flora	shrub/ sapling	canopy/ subcanopy
lw08	untreated mine waste	4	255	95	1	0	1	1	4	0	0
lw09	contaminated native soil	3	245	1	85	2	4	1	23	35	85
momines01	untreated mine waste	4	327	98	0	0	0	0	2	0	0
momines02	untreated mine waste	0	-	99	0	0	0	0	1	1	0
momines03	untreated mine waste	11	295	98	1	0	0	1	2	0	0
nadist01	reference bottom	1	13	6	60	7	5	1	42	63	90
nadist02	reference summit	3	57	0	92	0	3	5	18	44	82
nadist03	reference bottom	0	-	9	90	1	3	6	36	72	80
nadist04	reference summit	5	285	0	94	1	4	3	18	50	70
nadist05	reference bottom	2	238	1	65	15	4	3	30	55	60
nadist06	reference summit	2	247	0	91	0	5	2	21	49	67
nadist07	reference bottom	1	240	1	91	3	4	2	24	23	60
national01	untreated mine waste	4	106	96	1	0	1	0	4	0	0
national02	untreated mine waste	25	147	98	1	0	1	0	2	0	0
national03	untreated mine waste	29	34	64	4	0	1	1	26	3	0
national04	contaminated native soil	2	42	42	23	10	6	9	17	92	92
national05	contaminated native soil	0	-	51	3	0	3	8	40	21	73
stjoe01	reference summit	2	119	3	70	0	3	18	30	8	70
stjoe03	reference bottom	1	40	4	70	22	5	5	45	18	80
stjoe04	reference summit	5	295	1	84	0	3	4	22	5	55
stjoe06	reference summit	8	350	0	89	1	3	3	20	12	73
stjoe07	reference bottom	1	248	2	15	0	3	3	75	5	60
stjoe08	reference bottom	1	180	1	75	0	5	2	48	50	80
stjoe09	contaminated native soil	12	210	6	60	1	5	4	55	60	18
stjoe10	contaminated native soil	12	262	6	80	0	5	5	18	50	30
stjoe11	contaminated native soil	16	180	6	80	1	4	6	18	75	40
stjoe12	untreated mine waste	9	360	98	1	0	0	0	1	0	0
stjoe13	untreated mine waste	25	9	95	1	0	1	3	4	1	2
stjoe14	untreated mine waste	3	309	85	2	0	0	0	14	0	0

				Environmental Variable % Cover					Vegetation % Cover		
Plot	Plot type	slope	aspect	bare substrate	litter	native rock	tree root/bole	woody debris	ground- flora	shrub/ sapling	canopy/ subcanopy
stjoe15	untreated mine waste	0	-	89	1	0	0	0	10	0	0
stjoe16	revegetated mine waste	1	207	8	5	0	1	1	87	6	0
stjoe17	revegetated mine waste	1	186	4	10	0	1	0	90	4	0
stjoe18	revegetated mine waste	0	-	54	8	0	1	0	45	1	0
stjoe19	revegetated mine waste	0	-	50	7	0	1	0	40	1	0
stjoe20	revegetated mine waste	0	-	4	7	0	1	0	89	3	0
stjoe21	untreated mine waste	3	160	96	3	0	1	1	3	4	4
stjoe22	untreated mine waste	4	330	96	1	0	1	1	3	1	0
stjoe23	untreated mine waste	7	257	91	1	0	1	0	9	0	0
stjoe24	untreated mine waste	10	170	99	1	0	1	1	1	1	0
stjoe25	untreated mine waste	0	-	86	1	0	0	0	13	0	0
stjoe26	revegetated mine waste	0	-	3	8	0	1	1	86	4	0
stjoe29	revegetated mine waste	0	-	5	11	0	1	1	87	2	0
stjoe30	contaminated native soil	1	359	1	78	1	3	3	22	33	63
stjoe31	contaminated native soil	17	353	1	91	1	6	4	9	24	72
stjoe32	contaminated native soil	12	340	1	87	1	3	4	26	41	61
stjoe33	contaminated native soil	17	231	3	84	1	3	4	27	74	54
stjoe34	contaminated native soil	6	100	2	84	0	5	3	47	33	64
stjoe35	contaminated native soil	8	57	2	94	0	4	2	21	12	69
sweetwater01	contaminated native soil	11	215	0	78	1	3	3	67	63	54
sweetwater02	untreated mine waste	0	-	100	0	0	0	0	1	0	0
sweetwater03	untreated mine waste	1	13	99	1	0	0	1	0	0	0
sweetwater04	untreated mine waste	1	213	99	1	0	0	1	1	0	0
sweetwater05	contaminated native soil	6	201	0	91	1	3	2	34	53	56
sweetwater06	untreated mine waste	2	34	99	1	0	0	1	1	0	0
sweetwater07	contaminated native soil	9	320	0	95	1	2	2	38	63	57
westfork01	untreated mine waste	2	211	93	1	0	1	4	2	1	0
westfork02	untreated mine waste	2	292	99	1	0	0	1	1	0	0
westfork03	untreated mine waste	3	242	99	0	0	0	1	0	0	0

				Environmental Variable % Cover					Vegetation % Cover		
Plot	Plot type	slope	aspect	bare substrate	litter	native rock	tree root/bole	woody debris	ground- flora	shrub/ sapling	canopy/ subcanopy
westfork04	contaminated native soil	26	243	1	90	2	4	2	14	33	62
westfork05	contaminated native soil	26	9	13	74	6	6	4	34	53	89
yoder01	untreated mine waste	4	295	91	1	1	0	1	7	1	1
yoder02	untreated mine waste	0	-	89	1	0	0	1	10	0	0
yoder03	untreated mine waste	33	166	94	1	0	0	1	5	0	0